The HOW AND WHY Wonder Book of

0 552 86572 9   35p

ROBOTS AND ELECTRONIC BRAINS

# THE HOW AND WHY WONDER BOOK OF

ROBOTS
AND ELECTRONIC BRAINS

Written by
ROBERT SCHARFF

Illustrated by
DENNY McMAINS

Editorial Production
DONALD D. WOLF
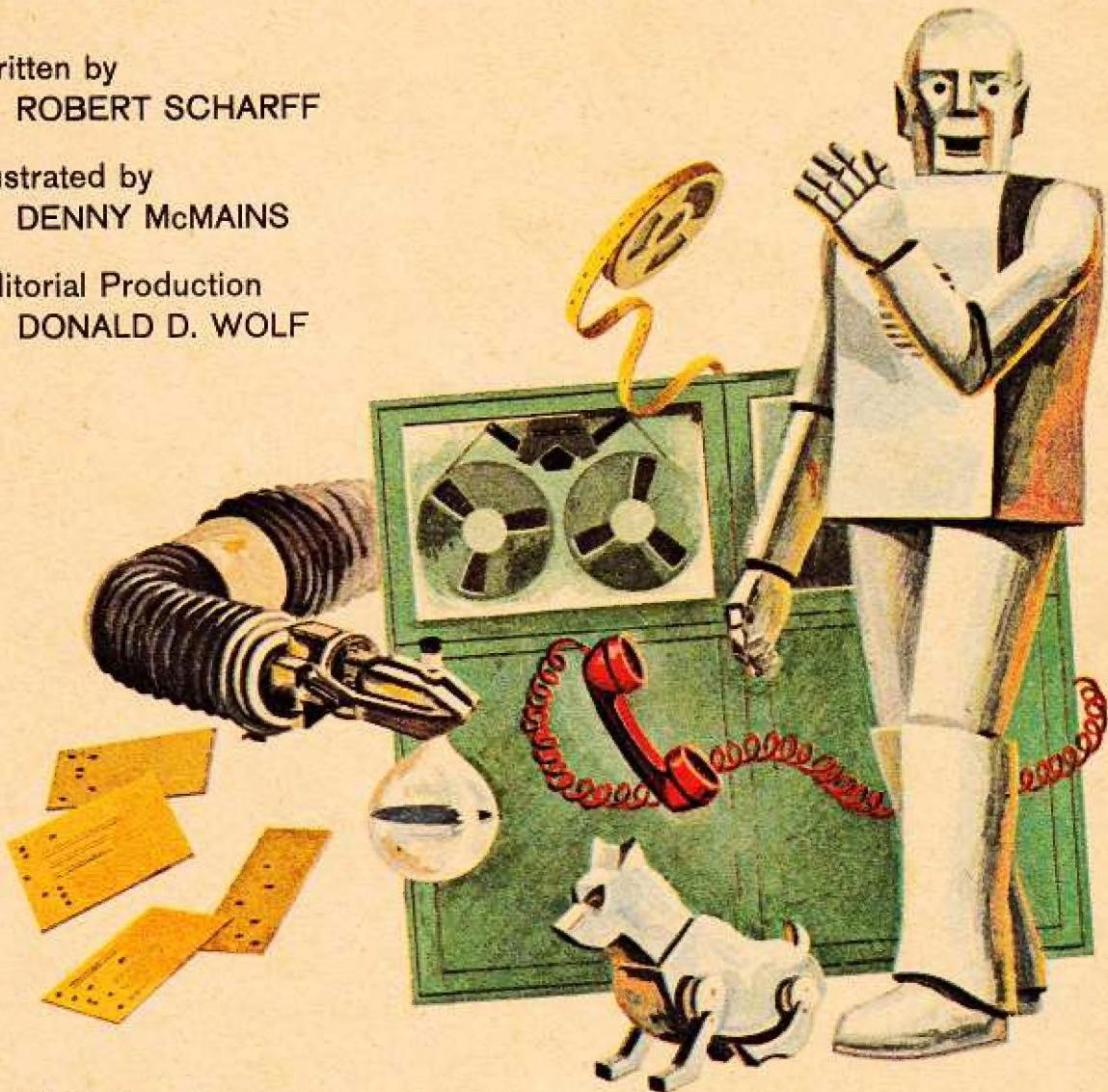
Edited under the supervision of
Dr. Paul E. Blackwood, Washington, D. C.

Text and illustrations approved by
Oakes A. White, Brooklyn Children's Museum, Brooklyn, N. Y.
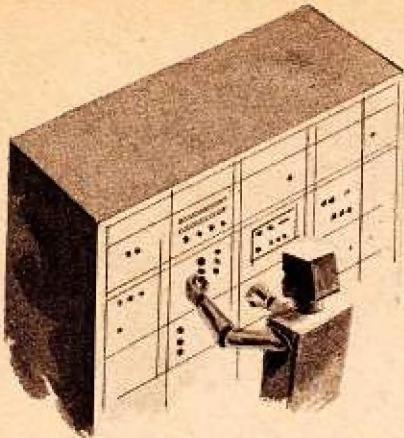
Introduction

Electronic computers have helped usher mankind into the Space Age. Without them it would be impossible for scientists to quickly supply crucial answers regarding flights into outer space. Robots and automatic computers are also helpful in practical ways as we learn in this *How and Why Wonder Book of Robots and Electronic Brains*. Through pictures and numerous examples, this book gives the reader an understanding of both the practical and theoretical application of modern computing devices.

Scientists are interested in discovering and testing basic concepts about phenomena and events in nature. Mathematicians develop mathematical ways of describing and predicting these events. The two groups support one another in making discoveries and in solving problems. Electronic computers offer a basis for the co-operation needed to solve problems. Some of these problems would not be solved even in a lifetime without the assistance of computers.

The advent of electronic computers and other forms of automation are resulting in social and economic changes of great significance, such as a shorter work week. To be well informed today, one needs to know about the uses and potential capacities of modern automatic devices. This *How and Why Wonder Book of Robots and Electronic Brains* will give a basis for understanding the many uses of electronic computers and will stimulate readers of all ages to think about the machines' effect on the future economic and scientific developments in our civilization.

Paul E. Blackwood

Contents

Robots in Our World

The word "robot" in this age of modern science still carries with it a feeling of both hope and fear. The hope is that machines built to work like men will make life for the human race much pleasanter and happier. The fear is that robots may one day take over the world and that they may become the masters of all mankind. After you have finished reading this book, you should be able to make up your mind as to whether robots offer hope or should be feared.
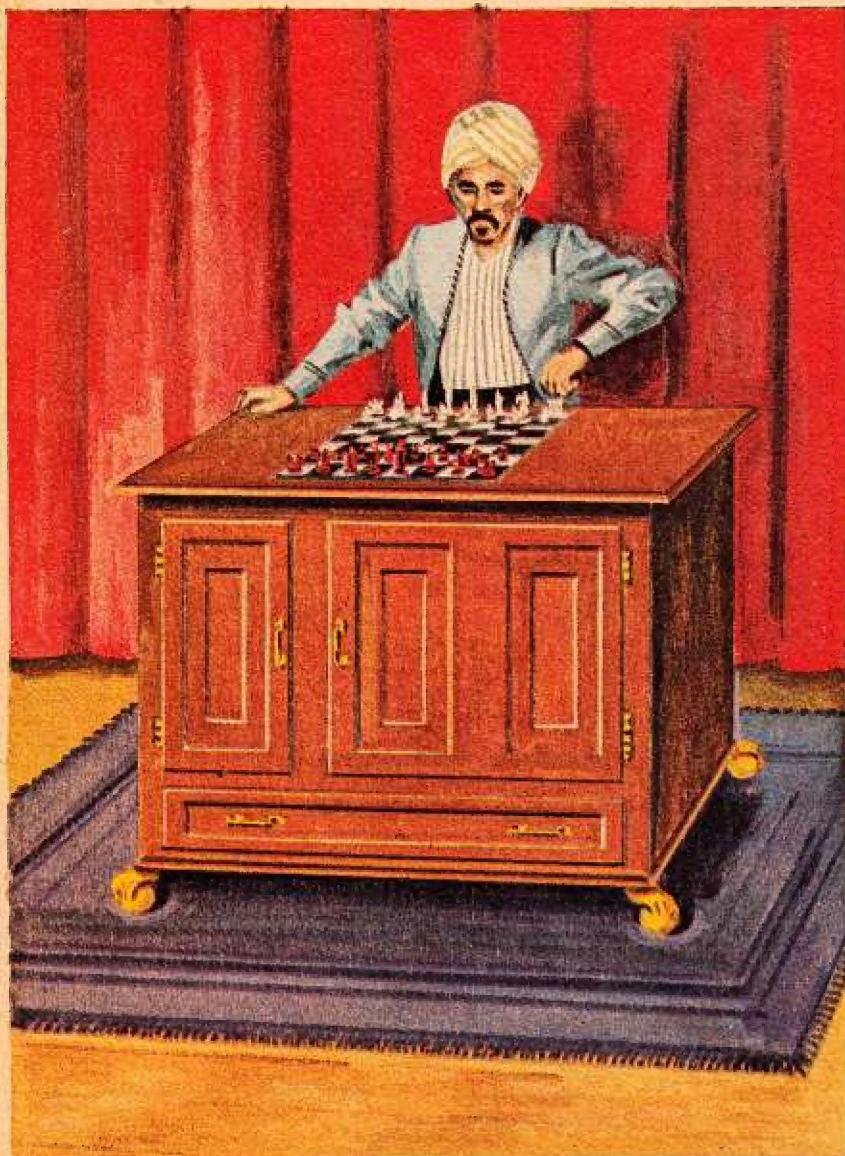
Von Kempelen's Chessplayer, here shown contemplating a move, was a clever fake, and no robot at all. The illustration below shows the midget who was an excellent chessplayer and who manipulated the automaton from his hiding place.
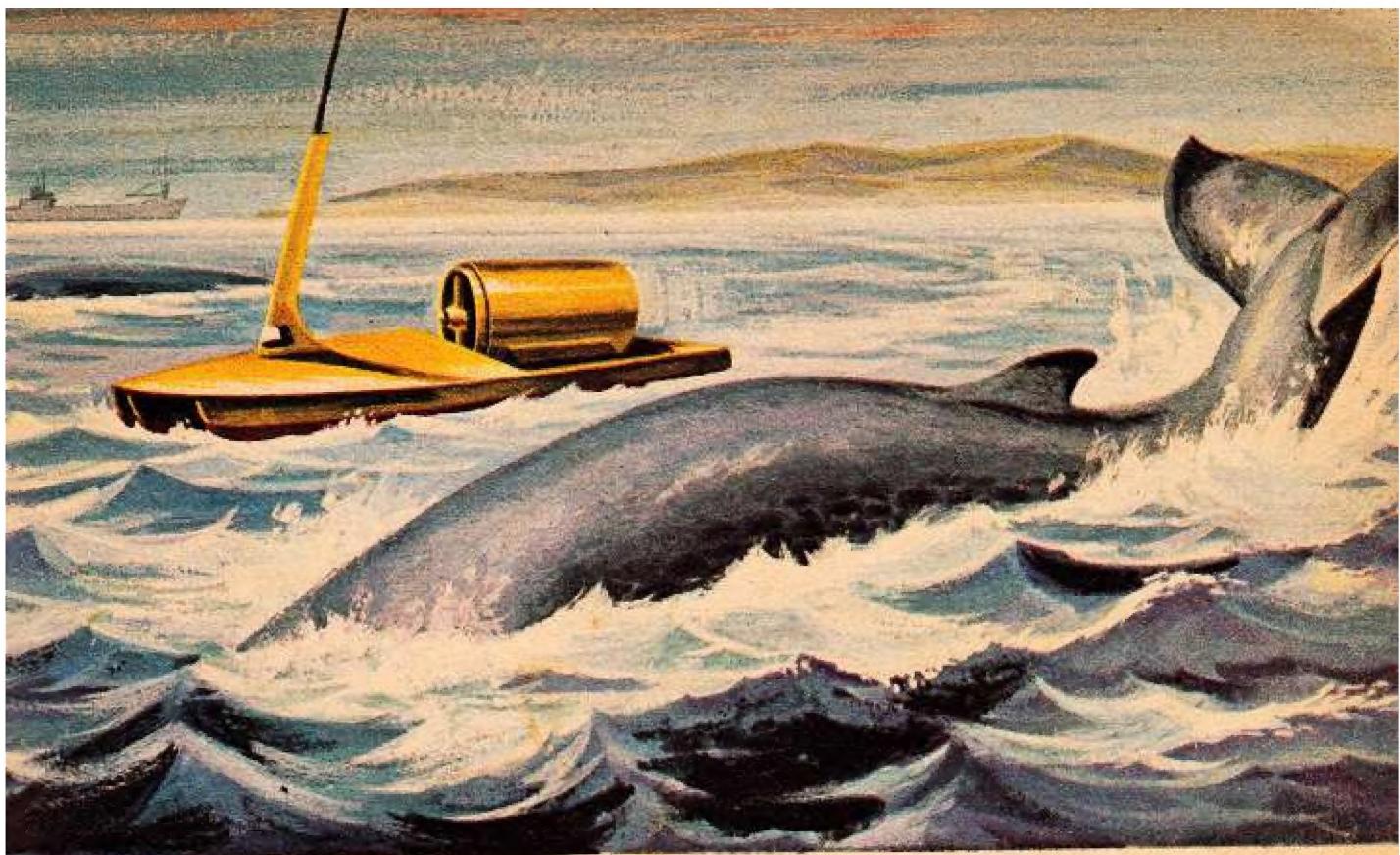
Scientists are finding many other uses for robot type devices. For example, a mechanized radio-controlled boat — called MOBY-DIC (*Motorized Observation Biotelemetry Yacht-Data Integration and Control*) — is employed as an unmanned on-the-spot observer of the social behaviour of whales and porpoises in their natural habitat. This information — not obtainable in captivity — is picked up by the robot's ears and eyes and transmitted for analysis to an oceanographic mother ship several miles away. These members of the marine mammal family seem to ignore the unassuming robot as long as it makes no hostile moves.

What are robots? Not everyone agrees about what a robot "is," but most dictionaries and encyclopedias define it as a piece of machinery that does a job you would expect a human being to do.

The idea of building a machine that can work and think like a man is not new. It has existed for centuries. Most early robot stories, however, were more fable than fact, like the "automatic" chess player devised by the German Wolfgang von Kempelen in 1768. This man-like machine had great success in playing against the best players of Europe until it was discovered that there was a midget inside the robot who played the game very well.

This robot was a fake; but scientists have been able to build electronic ones that really can play chess. The best of these machines is about as good as the average chess enthusiast but not as good as the chess Masters. In 1974, the first world championship for chess-playing machines was won by *Kaissa*, a machine from Russia.

Where did robots originate? The word *robot*, or artificial being, comes from the Czech word *robotnick*, an ancient name given to a serf or slave. It was introduced into our modern lan-
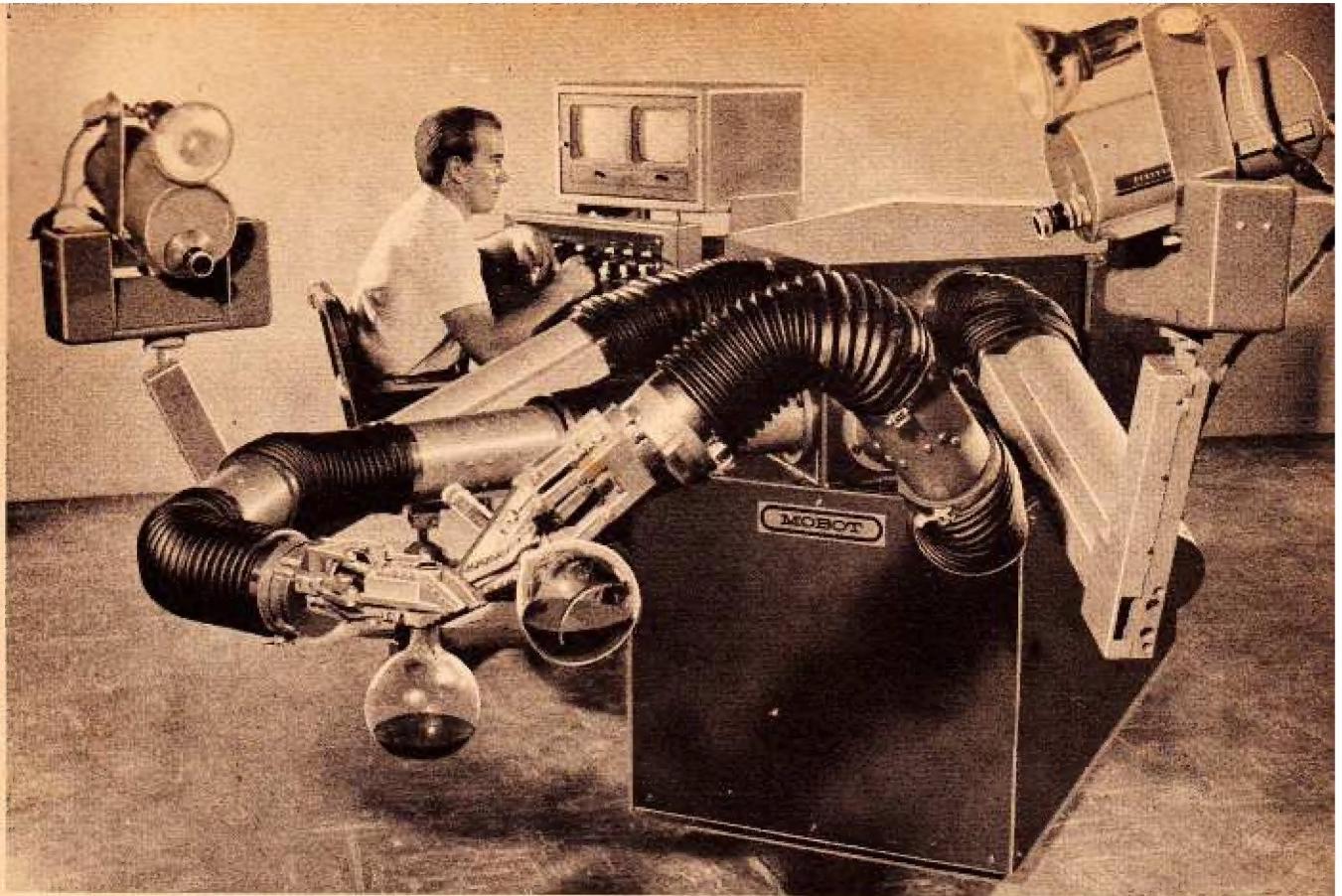
MOBOT, the gentle robot, is strong enough to bend iron bars, but can also handle laboratory glasses with ease.

guage in 1922 by a Czech writer, Karel Capek, in his play called *R.U.R.* The initials that make up the play's title stand for *Rossum's Universal Robots.*

In Capek's play, all the work in the world was done by man-like machines — the robots — which Rossum manufactured in very large numbers. Everything went along very smoothly on earth. All the needs and pleasures of mankind were being fulfilled, just as long as the robots had no feelings of their own. Then, one day, the manager of the factory decided to make superior robots that had all the human feelings of happiness and pain. When this happened, the robots revolted against their human masters and destroyed all mankind.

Since Capek's play, the robot has become a favourite character of the science-fiction writers. Today, however, robots are no longer paper creations. Real robots are among us — running factories, translating languages, charting the paths of rockets, and calculating or forecasting almost anything we wish to know — though they are called many different names.

Most robots do not look like the tin can mechanical men that we see in comic strips, in films, or on television. In actual fact, our amazing new robots now being designed and built bear little likeness to man. In their work, however, they duplicate the skills performed by men and often do them much better.

What do robots look like?

You see robots at work around your home everyday although you may not

6

have considered them as such. But, according to one definition, washing machines, toasters, automatic coffeepots, electric heaters, and so forth, are all robots. They are machines that do the work that you would expect a human being to do.

There are also robots used in factories to stack all sorts of objects. Once programmed they can carry out their jobs tirelessly and efficiently, and they do not get bored.

They can be developed to do other menial jobs like table-laying and clearing, washing and bed-making. A table-clearing robot has been demonstrated at Queen Mary's College, London already.

Robots have been made to do jobs too dangerous for men. An early one was known as *Mobot*. A more recent one, designed in the U.S.A. in 1969 by the Atomic Energy Commission and the National Aeronautics and Space Administration has been called the first humanoid. It is intended to be controlled by a computer and we shall learn about computers later on. So one robot will guide another. This humanoid will work in dangerous places where the conditions make it impossible for man, such as those contaminated by radiation. It could test a rocket in operation or be used to explore a planet. It has artificial arms so it can feel and pick up things, T.V. cameras to see with and sound pick-up to hear with. It moves on a flatbed vehicle, can communicate with a computer using a teletype machine and is steered and controlled by radio.

All of the satellites launched by the U.S.A. into outer space have had robots on board. They have sent back to their masters on earth important data concerning temperature, radiation, effects of gravity and so on. Neil Armstrong, the first man on the moon, could not have landed and spoken his famous words without the help of robots.

Instead of landing men on the moon, the Russians have used robots called *lunokhods* to explore its surface.

When spaceships land on Mars or Venus they will have similar types of robot on board instead of humans. These robots will map the surfaces of the planet, make necessary geological studies, explore unknown regions and eventually build landing areas for future spaceships. They will help make it safer for humans when they arrive later.

While other robots look a great deal

How do robots work?

different from Mobot, their basic operation is the same. The most important part of their operation is the man who gives them their instructions. These instructions are given to the machine through wires or by radio (or may be stored in the robot itself). To make the machine follow its master's wishes, power must be supplied either through other wires or from a self-contained source such as a battery.

The robot, equipped with instructions and power, may contain some type of sensing device, which could be a television camera, a radiation (Geiger)
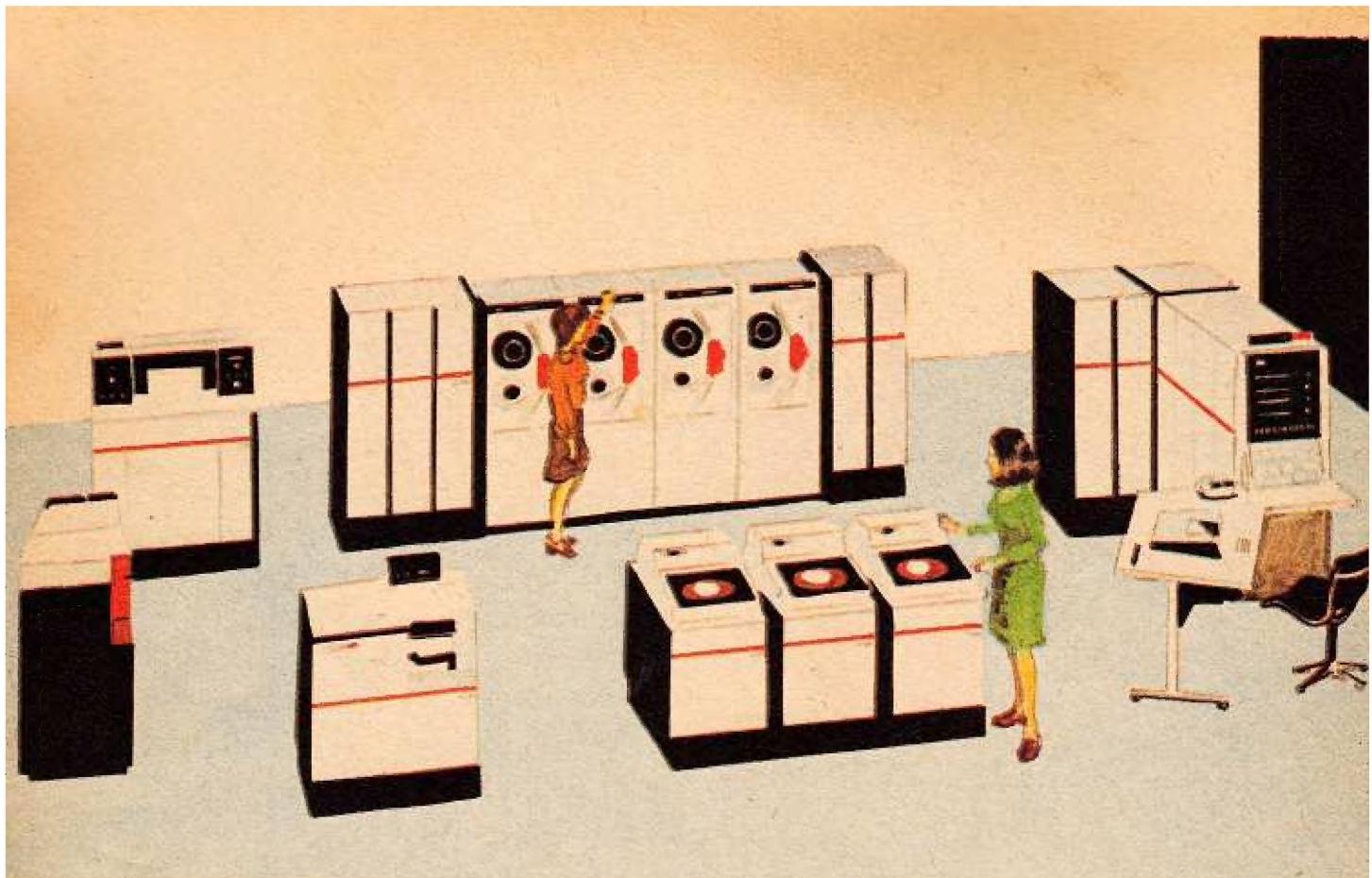
Computers are used in many industries, in hours they solve mathematical problems that would take a man more than a lifetime. They are used in jet aircraft design, in missile control, in payroll make up, in calculations of the petroleum industry, and innumerable other applications.

counter, or a magnetometer (a piece of equipment used to find oil and other minerals). These sensing devices can be compared to the human's eyes and nose and allow the robot to gather the information to return to its operator.

The robot may have grasping devices similar to human arms and hands. Following instructions, the robot can pick up and move objects, just as a man might do. To do this, some type of arrangement is usually necessary to tell the operator how hard the hands or claws are gripping, plus other information. (In the case of Mobot, microphones on the wrists allow the operator

to "hear" the hands at work.) Some robots are powerful enough to tie iron bars into knots and lift over 20 tons of weight, and yet they are so sensitive that they can make cakes or pour glasses of water without any breakage.

Robots with Electronic Brains

Of all the robots that are among us today, those with electronic brains, called *computers*, are in the process of revolutionising our way of life. These robotistic devices eliminate the drudgery from many jobs and offer a great deal more leisure time to their human masters. While they were originally developed to aid in the solution of certain scientific problems, computers have turned out to be so generally useful that they are now being employed in many different types of work.

What are computers? If you were to look up the word "computer" in a dictionary, you would find it defined as "a machine that solves mathematical problems." Today, these amazing machines range from small desk devices for "doing sums" to room size units that can solve complex mathematical problems in less time than the twinkling of an eye.

While computers are sometimes called "thinking machines," or "robots that think," these names are misleading. No machine can really *think* in the usual sense, but these computers do many important and exciting things. By using their ability to solve complex mathematical problems, computers can predict the paths of satellites, guide ballistics missiles in flight, or spot high-altitude weather conditions and warn us of storms, tornadoes and hurricanes

faster and more accurately than any weather-forecasting device ever used.

Computers do mathematical problems in hours or even minutes that would take more than a man's lifetime to solve with paper and pencil. They help major industry perform its manufacturing operations better for, with their aid, skilled men can control complex combinations of machines.

The industries shown on pages 8 and 9 are just a few examples of today's uses of computers. Innumerable other uses could be mentioned.

Computers affect our lives in many ways. Every day they handle millions of pay cheques and bank accounts. Business corporations use them to help run their office. Motor-car manufacturers must keep 60,000 spare parts for their different models. Just think what a difficult task it is to keep control of this number. It would be impossible without computers.

What are the uses of computers?

Computers help in the delivery of the finished product to the shops by telling the delivery men the address of the shop, how many articles to deliver and the best way to get there. They will print the bill for the shopkeeper and, if he forgets to pay, they will send him a reminder.

Governments use them to help run our countries and they keep track of our sky-rocketing population.

But computers go far beyond these uses. They influence the design of almost every product of advanced technology, jet aircraft, nuclear reactors, power plants, bridges and chemical factories. Managers of oil refineries also use them to tell them what products to make from oil.

The huge Saturn rocket was designed at the Space Flight Centre in Huntsville, Alabama with the help of giant computers. It was "flown" many times on these computers before it was launched into space. This technique is known as *simulation*. It is very complex but, basically, we try to act out the likely behaviour of the rocket using thousands of mathematical calculations which can only be done on a computer. The sort of things we need to find out are, how much stress the metal of a rocket can withstand or which is its flight path to reach the moon, given the pull of the earth's and the moon's gravity and other important factors.

The electronic computer, among the foremost American inventions of this century, was not an overnight discovery. It is the fruit of the practical science of mathematics and has its roots far in the past.

Who invented computers?

From counting on his fingers, man gradually progressed to pebbles on the ground . . . to pellets of bronze, sliding on a grooved board . . . to beads strung on framed wires . . . and to the abacus. (See illustration, pages 12-13) The first adding machine, invented in 1642, was followed by a four-operation arithmetic machine composed of a difference engine that performed calculations, a mechanical tabulator, a punch-paper control system, and a differential analyzer. Although these inventions increased computation speeds, they failed to fulfil the needs of our complex world.

More than a century ago, Charles Babbage, an English mathematician, designed an "analytical engine" which was an automatic computing machine as we use the term today. His idea was not completely fulfilled because no one could make the required mechanical parts with the needed accuracy.

In 1936, a young Harvard physicist, Professor Howard Aiken, happened

upon some of the writings of Dr. Babbage. Like Babbage, Dr. Aiken saw the possibility of a robot that could do the thinking of hundreds of men in a fraction of the time it took any one of them to work out routine mathematical problems. Aiken teamed up with other researchers and, by 1944, they built the first workable computer.

Two years later, the first general-purpose, all-electronic computer, called the ENIAC computer (from Electric Numerical Integrator and Calculator), was built.

ENIAC was followed by machines with names like UNIVAC and STRETCH. These were used in the 1950s and known as first generation computers. The speed of advance has been such that in the 1970s we are using third generation machines many times more powerful than those of the first generation. These are known by names such as 1110 or 370/168.

There are two basic types of computers

What kinds of computers are there?

in use today — *analogue* and *digital*. While they are very unlike in their construction, operation and use, both determine a given amount or quantity. The analogue type determines its quantity by measurement of how much while the digital type determines its quantity by counting how many.

An analogue computer is usually built

What is an analogue computer?

to be an *analogy* or a physical likeness of the problem that it is designed to solve. It may work, however, with physical quantities far different from those connected with the problem it is solving. Usually the answers are recorded on a calibrated scale, traced on a graph by a pen, indicated on a plotting board, or shown on a dial. An analogue computer is generally designed to solve a single problem, or a specific class of problems.

There are many common uses for simple analogue devices. One example is the familiar car speedometer. It changes the rate of turning of the wheel's axle into a numerical value of speed in terms of miles per hour. As we know, the more rapidly the car's axle turns, the higher the speed we read on the speedometer. In this case, we are interested in the speed of the vehicle rather than how fast the axle is turning. But the analogy or physical quantity of this speed is the axle turning. Slide rules, thermometers, clocks, and weight scales are examples of this type of computer.
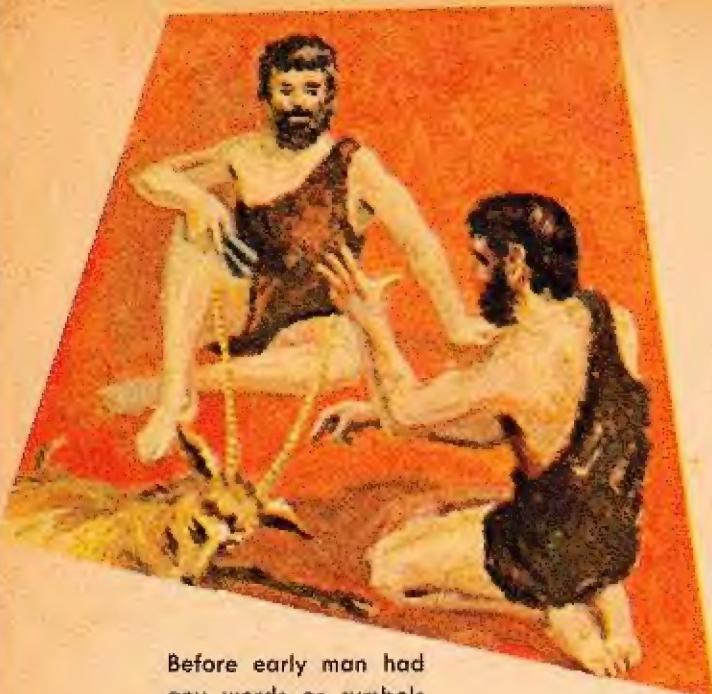
Before early man had any words or symbols for numbers, he used his fingers to count.

Many primitives, having advanced from finger-counting, used pebbles as counters. Peruvian Incas used knotted ropes called quipus for counting.

The early abacus was nothing but pebbles in grooves in the sand.

While the abacus has had many shapes and different names, depending on when and where it was used, its basic operation remains unchanged. It has individual columns with beads or marbles. The columns are arranged in the numeral position or decimal system used in the ancient Near East. Let's look at the earliest, the counting board of the Babylonian traders: three rows of pebbles; no column can have more than 9 pebbles. Let's add 263 to 349. First set up the pebbles to indicate 263: 2 hundreds, 6 tens and 3 units. Now add pebbles to signify 349: 3 hundreds, 4 tens and 9 units. Since no column can have more than 9 pebbles, move the pebbles over from right to left and you have as result 6 hundreds, 1 ten and 2 units, or 612.

The Roman abacus was made of metal, and small balls were used in each column.

12
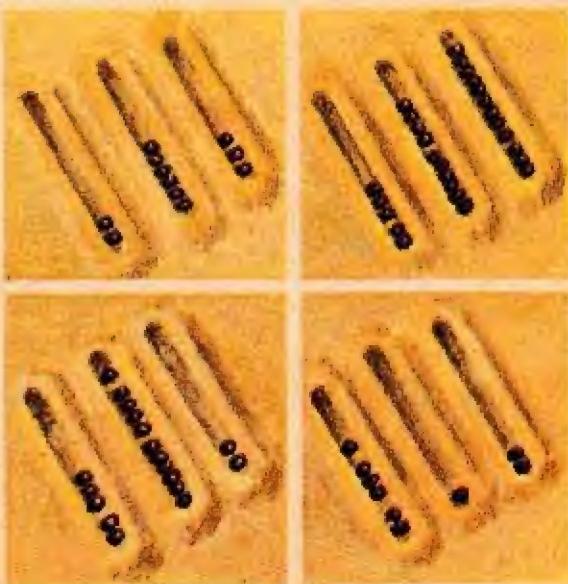
A few years ago, a Chinese-American book-keeper with an abacus won a race against an electronic calculating machine.
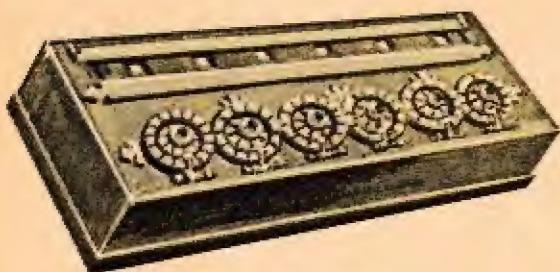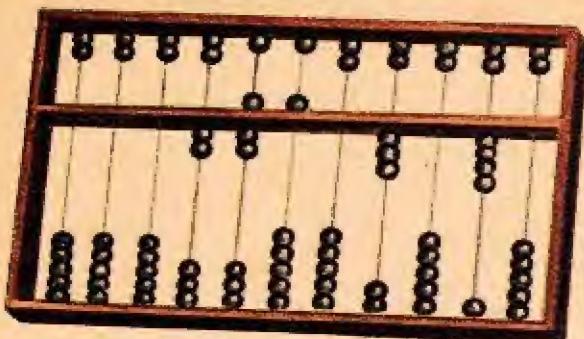
The Pascal adding machine of 1642 (above) and Burrough's (below) were only stepping-stones to the modern "miracles."
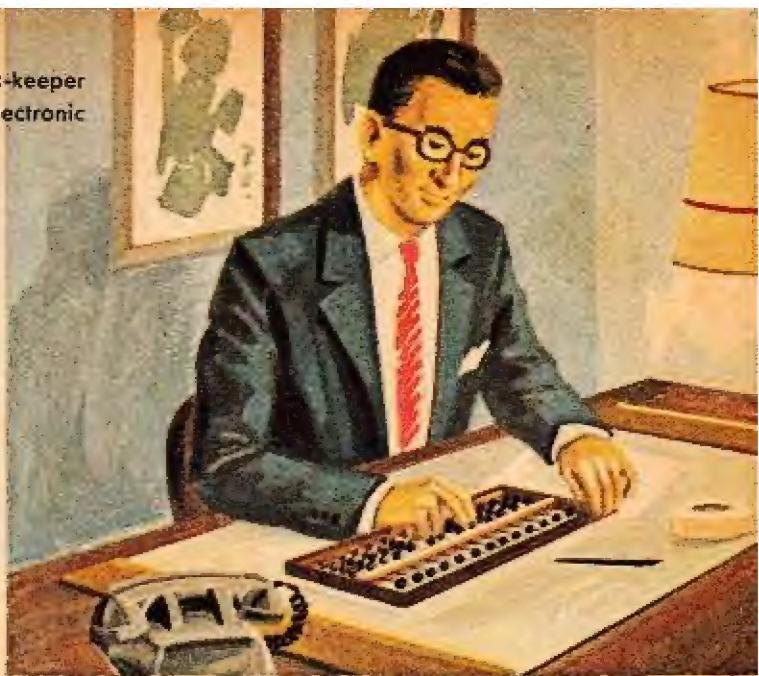
The beads above the crossbar on a Chinese abacus are called quints and count 5 each when pushed down to the bar; the beads below count 1 each when pushed up to the bar. Each wire strung with beads is called a column and represents one column of figures in the decimal system. The figure shown in the abacus above left is: 27,503,040.

FLEXIBLE CABLE

COUNTER

MAGNET
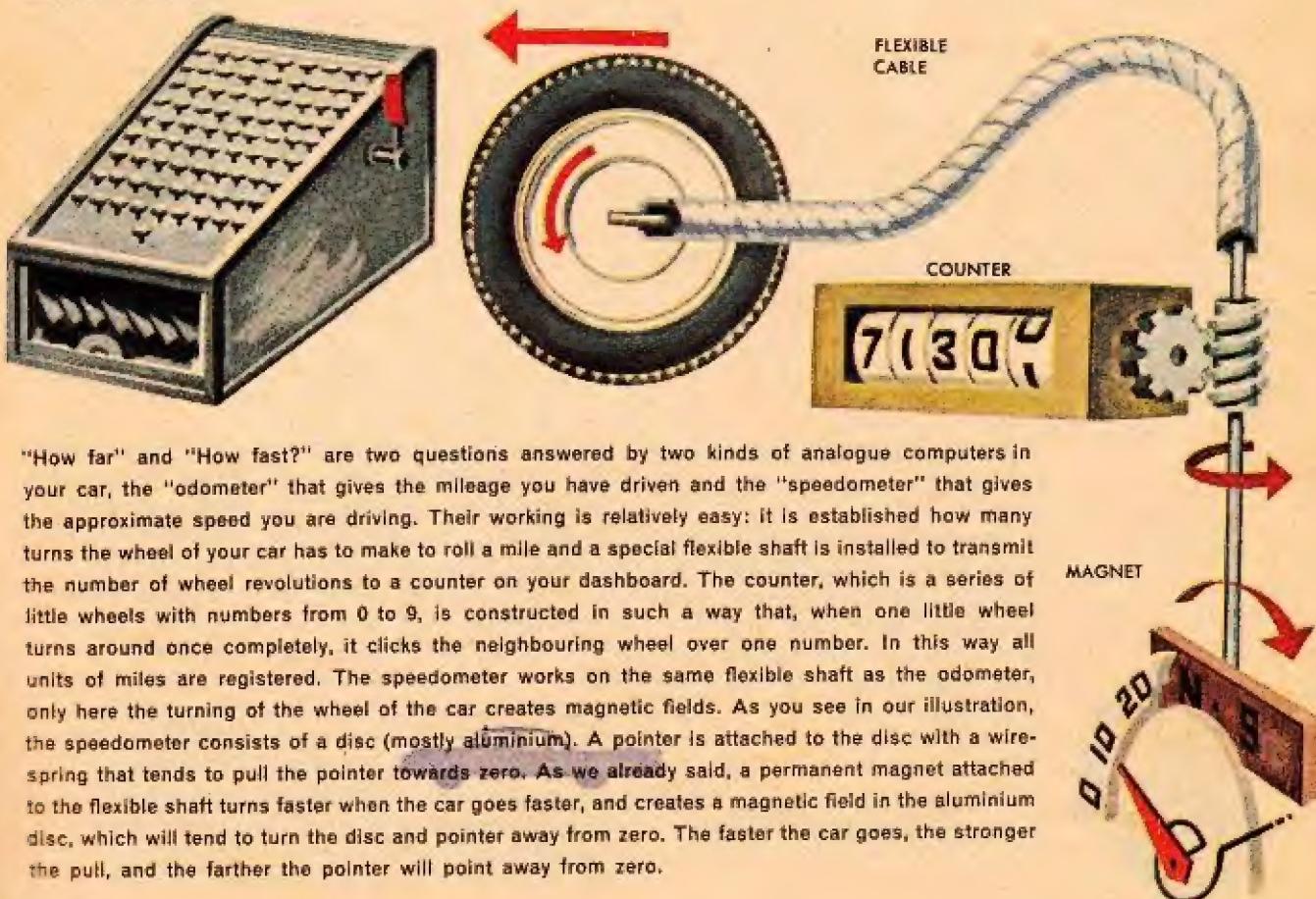
"How far" and "How fast?" are two questions answered by two kinds of analogue computers in your car, the "odometer" that gives the mileage you have driven and the "speedometer" that gives the approximate speed you are driving. Their working is relatively easy: it is established how many turns the wheel of your car has to make to roll a mile and a special flexible shaft is installed to transmit the number of wheel revolutions to a counter on your dashboard. The counter, which is a series of little wheels with numbers from 0 to 9, is constructed in such a way that, when one little wheel turns around once completely, it clicks the neighbouring wheel over one number. In this way all units of miles are registered. The speedometer works on the same flexible shaft as the odometer, only here the turning of the wheel of the car creates magnetic fields. As you see in our illustration, the speedometer consists of a disc (mostly aluminium). A pointer is attached to the disc with a wire-spring that tends to pull the pointer towards zero. As we already said, a permanent magnet attached to the flexible shaft turns faster when the car goes faster, and creates a magnetic field in the aluminium disc, which will tend to turn the disc and pointer away from zero. The faster the car goes, the stronger the pull, and the farther the pointer will point away from zero.

While these examples of analogue computers are quite simple ones, this type is also used for many complex purposes. The electronic kind, for instance, is used for navigation, missile guidance and anti-aircraft fire control. The latter, called gun director computers, are used to aim and fire guns at hostile planes. If you have ever tried to shoot a rifle at a moving target, you can imagine the complexity of a computer required to aim a gun and hit a hostile plane above 40,000 feet in the air and travelling at speeds higher than 600 miles per hour. No human being can solve all the calculations — speed of the wind, direction of the plane, how fast it is going, etc. — quickly enough to do this job, but an electronic analogue computer can do it with ease.
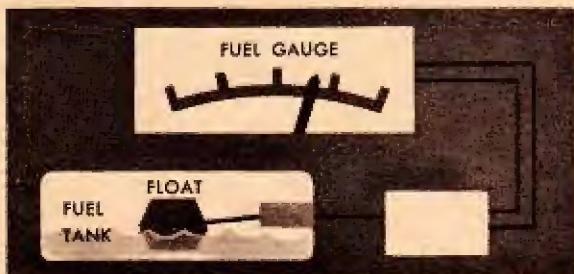
The fuel gauge of a car is another example of an analogue computer. It indicates what proportion of the tank is filled with petrol.

Digital computers are the most widely used computing robots today, because they are a great deal more accurate and will do more types of work than the analogue types. The digital computers do not measure; they count. They owe their name to the counting number on our ten fingers or *digits*. Because we have 10 digits instead of twelve, or six, or eight, most computation is based on the familiar *decimal* system: 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9.

What is a digital computer?

The simplest digital computer that we have is our fingers. Problems can be solved by counting them. A more complex digital computer with which we are familiar is the desk calculator. This machine can do everything — add, subtract, multiply and divide.

The modern automatic electronic digital computer, often called a *data-processing system,* can carry out a long series of arithmetical and logical operations on the basis of instructions given it at the start of the problem. Logical operations include such work as sorting, selecting, comparing, and matching various kinds of information.

How a Computer Works

All modern digital computers have three basic steps in their operation. Information or data must be fed into the computer — *input.* The information must be rearranged and solved in an orderly way — *processing.* The answer or solution must be fed back to the inquirer in an understandable form — *output.*

A human being must give the computer complete instructions before it can solve a problem. A

What is meant by input?

set of instructions is called a *programme* and is prepared by someone called a *programmer.* It is his job to study the problem, plan its solution and
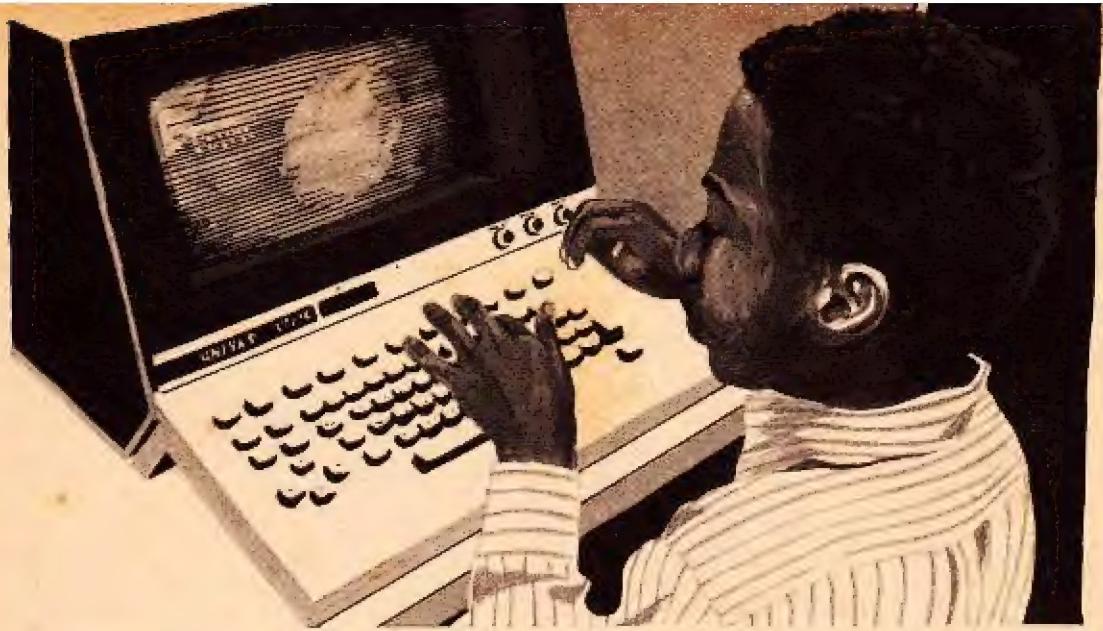
Our picture shows a child using a videotape machine.

write the programme which will carry out the plan. The programme is put into the computer followed by the data on which the programme must work. Without the programmer the computer would be useless.

The programme and data may be fed into the computer in various ways— through punched cards, punched paper tape, magnetic tape, magnetic discs or drums from paper inscribed with magnetic ink. Typescript can be read with devices called *optical readers*. One of the newest methods is a *videoscope* which is made up of a television screen and a typewriter keyboard. You can type a message which appears on the screen then, when it is correct, you depress a 'send' key and the message is put into the computer.

The processing operation is carried on

What is meant by processing?

within the computer itself. By using its various parts or elements, the computer calculates, sorts, matches, compares, and selects until it arrives at the desired answer to the problem given it.

While this processing operation is going on, the entire procedure is checked by a man, called the *operator*, at the computer's control panel. It is his duty to make sure that the computer is functioning in the proper manner. He can start and stop the computer and regulate its activity. He can send in new instructions or corrections given to him by the programmer, and can test various parts of the computer to see if they are working normally.

On most larger and modern machines much of the work of an operator is done by sets of programmes held inside the computer which are called an *operating system* and which tell the computer what to do. The operator talks to the operating system and viceversa by means of a typewriter or videoscope called the *computer consul*. This means the operator can be asked for a magnetic tape to read—"Please let me have a magnetic tape to read"— and after he has placed the tape on a reading device for use by the computer he can type in "O.K. magnetic tape is

15

loaded." The operating system will then organise the electronics of the computer system to read data from the magnetic tape.

After doing its work the computer gives its answers. Normally these are printed out on a printer or a videoscope screen. If the answers are required later they can be stored on punched cards, magnetic tapes or discs and the computer will arrange to print them out as required.

What is meant by output?

Nowadays, by using telephone networks and other special equipment, data and programmes can be fed into a large computer from thousands of miles away and answers can be fed back.

One day you may have a videoscope in your home and you will use it to order goods from the supermarket or to inquire about some information from a library when you do your homework.

One of the hardest points to understand about the operation of a computer is how it can make a logical decision. When we come to a logical decision of a problem, we do so by a process of thinking or reasoning. We search our memories or look into books for the facts on the subject and make our decision based on these facts.

What is the computer's logic?

While a computer cannot think or reason as we do, it reaches its logical decisions from the facts given to it by its programmer.

Possibly the simplest example of a computer-like system is the ordinary light switch. The problem in this case is: when the switch is closed, are all conditions present for the bulb to light? The conditions are such facts as whether or not the electric current is on, the light bulb good, the room properly wired, etc. If the answer is "yes" to all the conditions, the bulb will light when the switch is turned on. The computer system, in effect, will be giving its logical answer based on the fact that all conditions are present for the bulb to light when the signal is given.

Another example of a computer-type device is the automatic toll collector seen on many motorways and bridges in

The automatic toll collector is a computer-type device. It makes "logical decisions" as to whether the proper amount of money has been deposited.

16
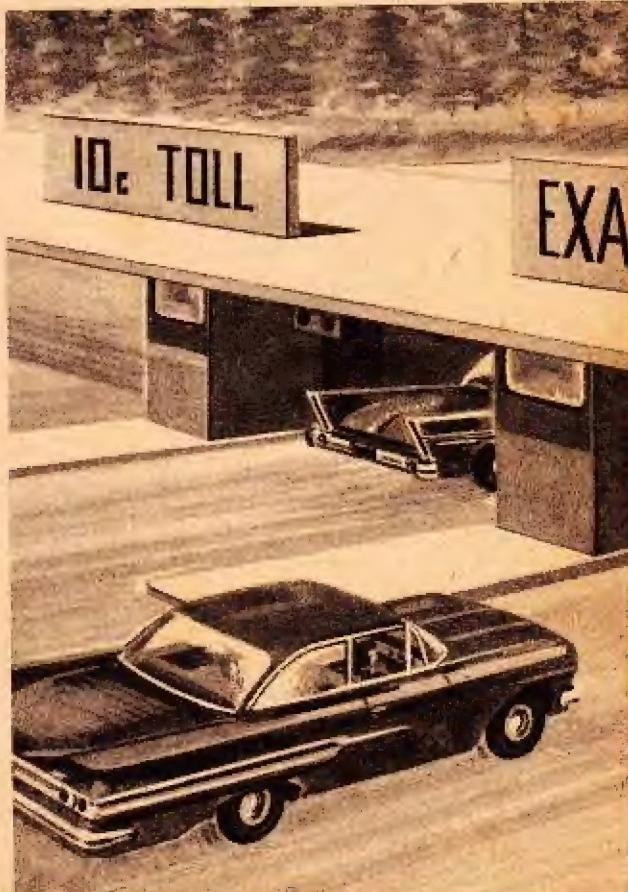
the United States. This device has the responsibility of making a logical decision as to whether or not the proper amount of money has been deposited by the driver to pay the toll.

Let us assume that a 10¢ toll is to be collected by the computer. This payment can be paid by depositing: one dime; two nickels; one nickel and five pennies; or ten pennies. The automatic toll collector will receive its input (the coins) and process them. It will then make its logical decision based on the fact as to whether or not the payment by the driver is sufficient. If the answer is "yes," the device will indicate to the driver that he may go ahead. However, if the computer reaches the logical decision that insufficient money has been deposited, it will flash a "stop" signal and will sound an alarm so that the guards are immediately notified of its negative decision.
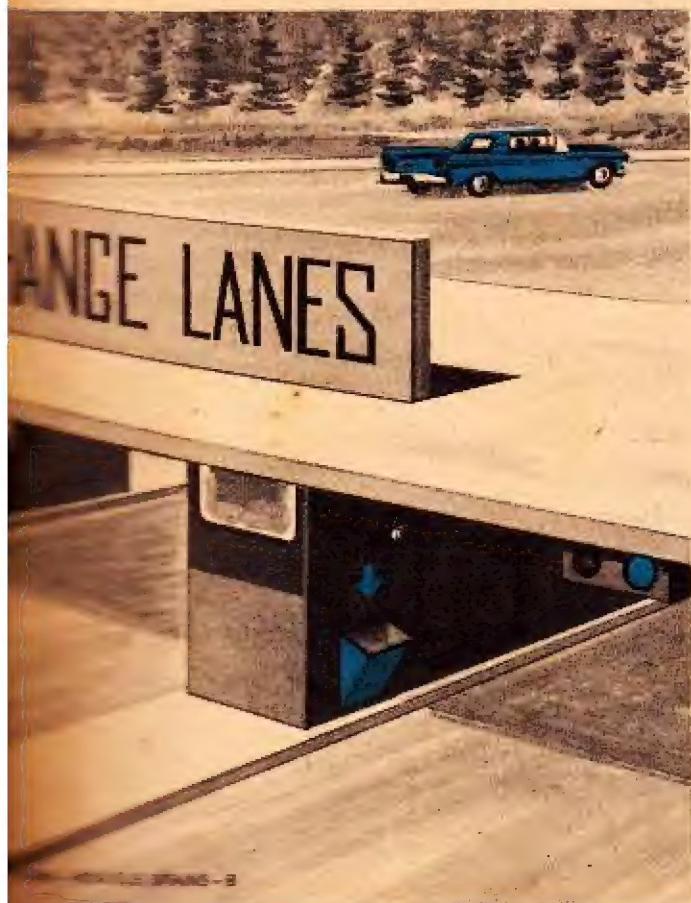
Although most digital computers cost

What do you need to build a simple computer? thousands of pounds, you can build one that will answer "yes" or "no" to simple questions for a few shillings. Here is what you need: two mechanical switches, a flashlight battery, a flashlight bulb and some wire. Remember, this is going to be a very simple computer. But it may surprise you all the same.
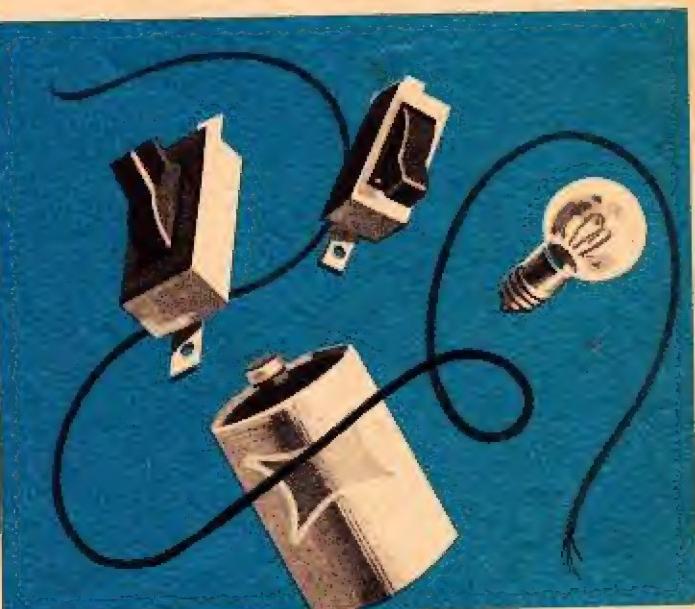
You can build a simple computer that will help you to understand the difficult subject of the working of electronic brains.

As a computer designer, your problem

How will it work? is this: with the parts named above, *build a computer that will give a recognizable signal when both of two necessary conditions are fulfilled.* You can consider the light bulb as the output of the computer, and the switches, each of which you may open or close by hand, as the inputs.

17

When the parts are properly connected, the computer will cause the bulb to light up, signalling, "Yes, both conditions are fulfilled." When the bulb is dark, the computer is saying, "No, both conditions are not fulfilled."

FIG. 1

FIG. 2

FIG. 3

You have probably already worked this out. Connect the switches with the battery and bulb as shown in figure 1. In this way, both switches must be closed for the bulb to light up. When only one switch is closed or when both are open, the bulb will be dark. Simple? Yes. But when you consider the logical operations performed by this computer, they are really quite impressive:

How does the computer give the answers?

It accepts information as input (the switches are open or closed).

It makes a decision based on the input (are both switches closed?).

It takes action based on this decision (either the bulb lights or remains unlit).

By rearranging the switches, you can build a computer that will decide automatically whether *either* of the switches are closed, and will light the bulb signalling, "Yes, at least one of the two possible conditions has been fulfilled." (Fig. 2.)

By combining the two circuits or arrangements, you can make a computer that will have four inputs and one output and will answer this question: "Are inputs one *and* two present? If they are, is *either* input three or input four present?" Having examined the inputs and found the answers to these two questions, the computer will go on to
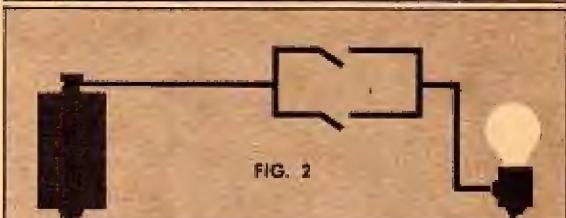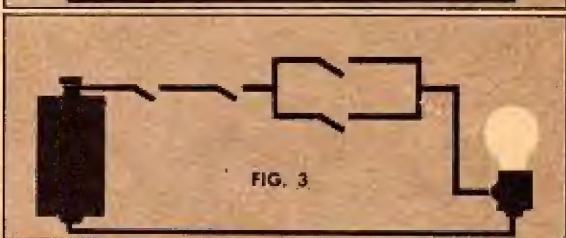
decide: "If the answer to *both* of these questions is 'yes,' light the bulb." Fig. 3 shows how you would wire this computer.

By this time the computer is doing a job of deciding that might actually be useful, and doing it a good deal faster than you could. If you do not believe this, build it and try to beat it.

Slightly more complicated arrangements of switches can be made to produce an output only when one input is present and the other is not. It is possible, by interconnecting circuits each of which does one logical operation, to create arrangements capable of answering all sorts of difficult questions. Computer kits that contain all the parts and drawings to make such arrangements are available at radio supply stores.

Instead of mechanical switches and flashlight bulbs, the modern computer uses much more rapid electronic devices for switching and registering, such as transistors, magnetic cores and silicon chips. The idea is the same as the computer just described.

The Elements of a Modern Computer

The modern electronic computer is not really a single piece of equipment but a series of five closely related parts or elements, each of which must function smoothly with the other four for the system to be useful. These five elements are: input, storage, arithmetic, control and output.

You are already familiar with two of these elements, the *input* and the *output*. If you were to see a real computer in action, you could watch the input-output equipment functioning, carrying information to the system and answers to the programmer. In our simple computer, the input is actually supplied by the movement of your hand, which opens or closes the two switches. Output is the flashlight bulb that lights up to signal "yes," stays dark when the answer to the question is "no."

The switches themselves perform an extremely important function in the computing circuit. **Where is the storage element?** They store the input, making it available to the computer throughout the process of computation. They store the information as to whether or not they are closed, since open means, "no input," and closed means, "input." You may never see the storage unit in a real computer since it is placed in a metal cabinet. But its function is exactly the same: it stores input in a form usable by the computer, and holds it ready for immediate use at any time during its operation.

In modern computers, the storage element also serves as a "memory" and information can be internally stored in the system by electro-mechanical, magnetic, or electronic devices, until needed. Stored information is readily available, can be referred to once or many times, and can also be replaced whenever desired. The data memorized by this element can be original information, reference tables, or instructions.
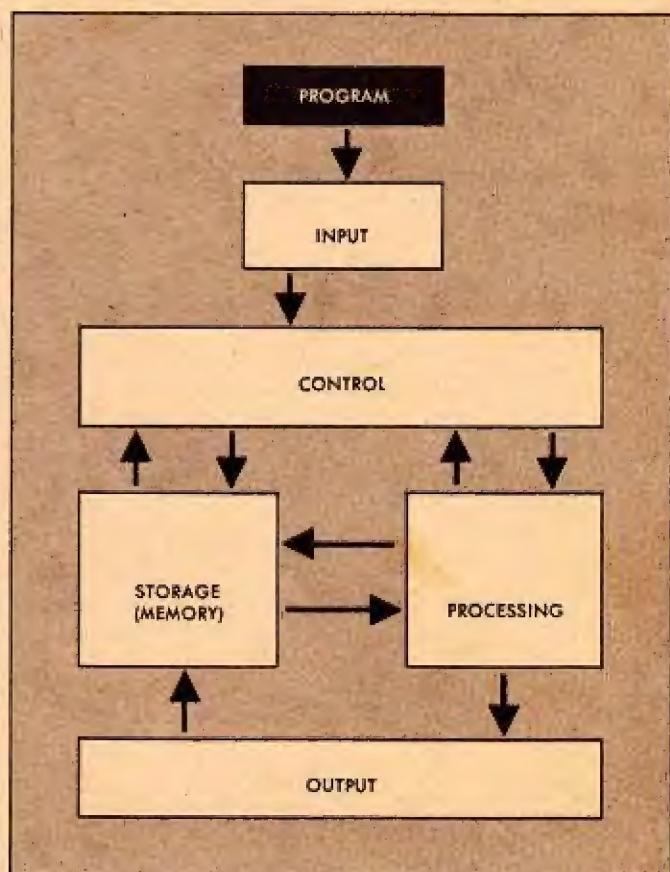
Parts of a digital computer and their functions.
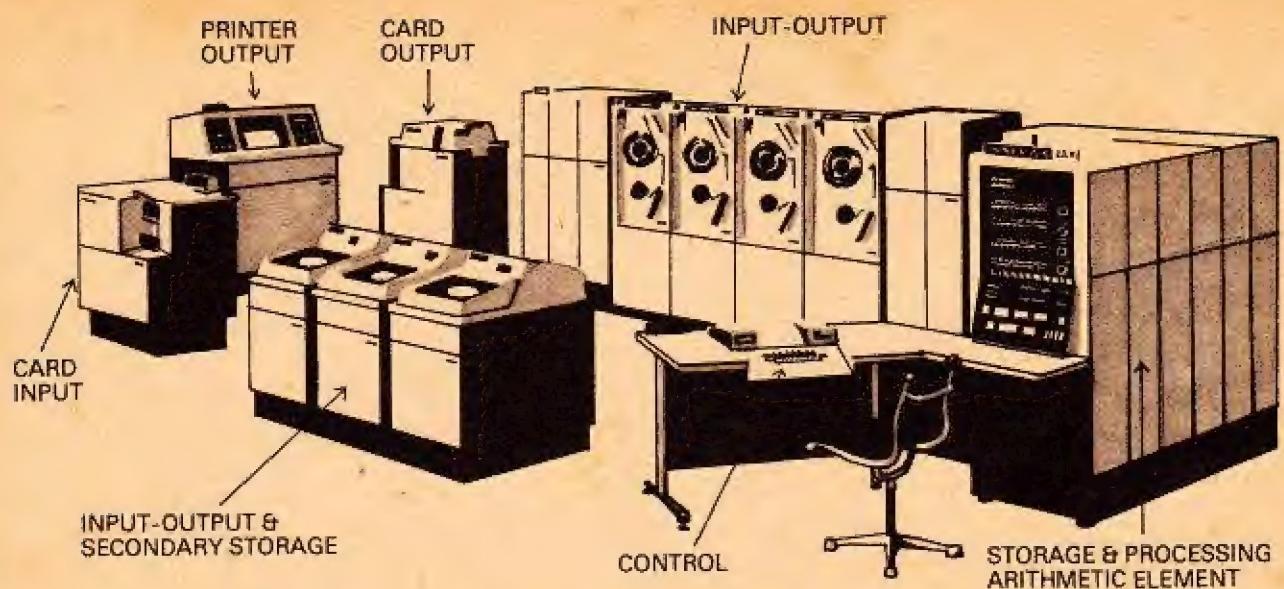
Actual arrangement and location of the various parts of a digital computer.

Each storage location is identified by an individual location number which is called an *address*. By means of these numerical addresses, the programmer can locate information and instructions as needed during the course of a problem. In other words, when the programmer wishes to take information out of the storage element he does not specify the data itself, but only its address. He knows that the information he wants is stored at that address because he himself stored it there earlier.

Actually the memory unit of the computer can be compared with a library, which stores books, just as the memory stores data. Each book in the library is given a code number, just as each bit of information in the memory elements receives a number. These book numbers permit the librarian to quickly find any book stored in the library without reading the titles on the books, just as the address permits the programmer to locate any data in the memory unit.

The speed of processing largely depends on the *access time* — the length of time required to obtain a number from storage and make it available to other elements of the computer system.

The element of the computer that **What element does the computation?** does the actual work of computation is called the arithmetic element. In our computer, this element is composed of the switches, wires, and battery. In most useful computers, the arithmetic element can add, subtract, multiply, divide, and compare numbers in a manner similar to a desk calculator, but at lightning speed. Complex calculations are always combinations of these basic operations. The arithmetic element also can make logical or reasoning decisions.

In most modern computers, the storage unit is completely separate from the arithmetic element, though connected to it. By sending electric currents back

20

and forth between themselves, these elements are able to communicate; the storage sends information to the arithmetic element for processing, and the arithmetic unit sends back the processed information to storage.

The lines of communication between

How do all the elements work together?

the storage and arithmetic elements in our model computer are fixed. In more complicated circuits or networks, however, there may be a number of alternative paths between storage and arithmetic elements. One path could lead to a network whose sole function was to add two numbers, another to a network which did nothing but compare the sizes of two numbers, and so forth. To decide which of these paths should be used each time a connection is made between the storage and arithmetic units, the computer has a control element.

The control unit in the computer can be compared with a railway switchyard control tower. There are many possible directions that the switching engine can be routed, but the man in the control tower pulls the proper levers to get it on the proper track so that it reaches its desired destination. In the computer, the control element, under instructions from the programmer, makes the necessary switch connections throughout the system so that the data can follow its proper path to reach the desired destination. Because of the speed required in routing information, the switching mechanism in modern computers, properly called the *auto-*

matic sequence control unit, is an electronic device rather than a mechanical one as it is in the railway control tower.

Now that you know the purpose of the

How does a computer compare with other methods of solving problems?

various parts of a computer, let us compare their functioning to the steps needed in solving a problem by paper and pencil methods. The *input* would correspond to the information given in the problem. The *arithmetic* element performs the same function as our manual calculations. *Storage* may be compared to the work papers on which we note intermediate answers. A knowledge of arithmetic rules *controls* our handling of the problem and our answers provide an *output*.

The control unit of a computer is like a railway control tower.
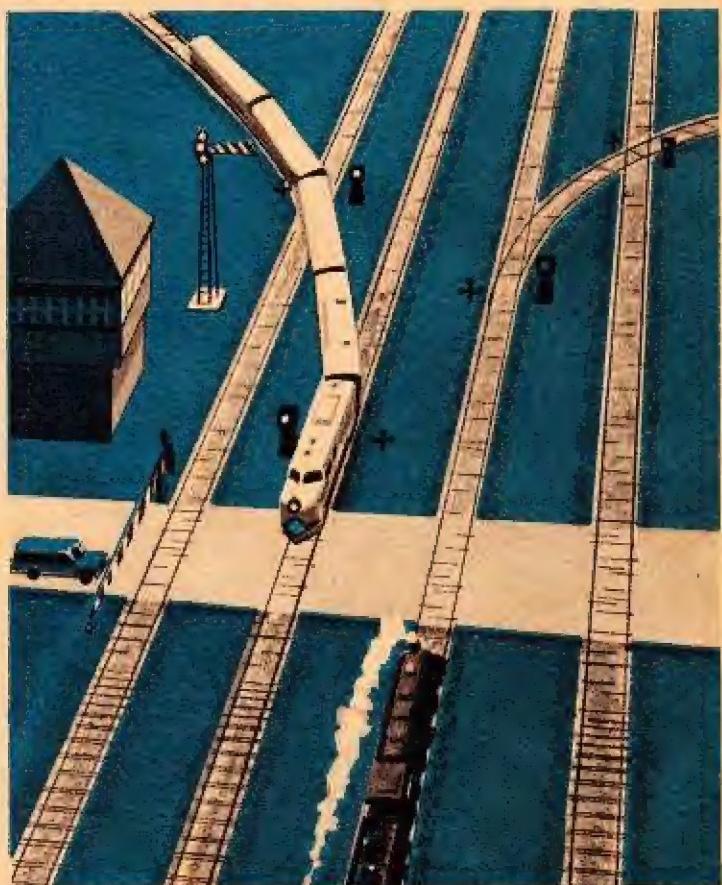
A Language for the Computer

The gap between man and machine is bridged by a language that is understandable to both. This language makes the operation of the computer possible. The language known as the binary number system, which was originally only used to represent and handle numbers, has been expanded to handle letters and symbols too. Although man can learn and understand the binary system, languages are being developed to enable computer users to express their problems more naturally. There are now over 100 different computer languages but the most widely used are Fortran and Algol for scientists and Cobol for business men.

The machine itself can only be worked by binary so the language of the user must be translated into binary. You will learn about this translation process in a later chapter.

What is the binary number system?

Binary (*bi* means two) uses only two symbols, 1 and 0, rather than the ten decimal numbers (0—9), and the twenty-six letters we normally use. The machine finds this system simple. You will too.

As you can see in the chart on page 23, the decimal numbers are compared with the corresponding binary symbols. Notice that shifting a decimal number one place to the left multiplies its value by ten, whereas shifting a binary number one position to the left multiplies its value by two. Thus, the symbol 1 in the binary system can be used to represent one, two, four, eight, or sixteen, depending on its position or place.

How do you count in the binary system?

Let us use the binary system to do some actual counting. To represent "zero" in binary, the symbol 0 is used. "One" is shown as 1, as in the decimal system. To show "two," when both available symbols already have been used we use some combination of the two. For example, the combination 1 0 can stand for "two." "Three" is 1 1. For "four," we must use three digits: 1 0 0. "Five" becomes 1 0 1; "six" 1 1 0; "seven," 1 1 1. We must add a fourth digit for "eight," which is 1 0 0 0. "Nine" is 1 0 0 1, and so forth.

Whereas the binary system suits computers, it is not nearly so practical for ordinary numerical problems as the decimal system because more digits are required to express numbers. For example, the number "thirty-nine" can be indicated in the decimal system by only two digits: a 3 and 9. Six digits would be needed in the binary system: "thirty-nine" would be written 1 0 0 1 1 1. The large number 1 0 0 0 0 0 0 0 0 0 in the binary system stands for "one thousand

DECIMAL SYSTEM

THIS NUMBER→	4	4	4	4
	THOUSANDS	HUNDREDS	TENS	ONES
	4x1000	4x100	4x10	4x1
MEANS→	4,000 +	400 +	40 +	4 = 4,444

2^4	2^3	2^2	2^1	2^0	
SIXTEENS	EIGHTS	FOURS	TWOS	ONES	
2x2x2x2	2x2x2	2x2	2	1	
16	8	4	2	1	DECIMAL EQUIVALENT
				1	1
			1	0	2
			1	1	3
		1	0	0	4
		1	0	1	5
		1	1	0	6
		1	1	1	7
	1	0	0	0	8
	1	0	0	1	9
	1	0	1	0	10
	1	0	1	1	11
	1	1	0	0	12
	1	1	0	1	13
	1	1	1	0	14
	1	1	1	1	15
1	0	0	0	0	16
1	0	0	0	1	17
1	0	0	1	0	18
1	0	0	1	1	19
1	0	1	0	0	20

digits are used to indicate numbers because of the lightning speed at which these machines operate.

The modern computers can store many digits in their memory units, too. Early ones were considered marvels if they had internal storage capacity for 1,000 *decimal* digits. New machines can store millions of digits on different storage devices. They can be made available on demand from a programmer in times ranging from nano seconds (hundreds of a millionth of a second) through microseconds (millionths of a second) to milliseconds (thousandths of a second).

What the programmer has written is known as the **How are decimal numbers changed to binary symbols?** *instruction* and one programme is made up of many lines of such instructions. Once he has written all of them down, he gives them to a punch operator. She uses a machine which looks like an ordinary typewriter. As fast as the information can be typed in on the keyboard —the keys of which are marked with Arabic numerals and English letters—the machine translates it into a pattern of binary ones or zeros onto the cards.

The cards get fed into a machine called a *card reader* which uses photoelectric cells to sense the position of the holes. It then sends the binary patterns to be stored in the computer memory. However these patterns represent the language the programmer used. The computer must now translate it into the language it can understand.

twenty-four." The same number in the decimal system is expressed by four digits (1,024). But, with modern computers, it does not matter how many

The binary system can be made to cor-

Can the binary system give other answers? respond to the conditions of an electric or electronic circuit — *on* or *off*. Using the principle of the switch, the "on" condition may represent "1," and "off"

may represent "0." The binary number 1 0 0 1 1 1, equivalent to the decimal number 39, would appear:

on   off   off   on   on   on

Because electronic circuits are used, a

Here we can see how information goes into a computer by means of a card. The information is changed from holes in a card to pulses along a wire by means of the photo-electric cells. The character image shows the presence or absence of a pulse. The inset shows the whole machine—the cards go into the hopper and come out into the stackers.

CARD READER

LIGHT SOURCE

80 COLUMNS

READ STATION

HOPPER

REJECT STACKER

STACKER

12 ROWS

HOLLERITH CARD

PHOTO-ELECTRIC CELLS

CHARACTER IMAGE ——— 0 1 0 1 0 0 0 1 0 0 0 0
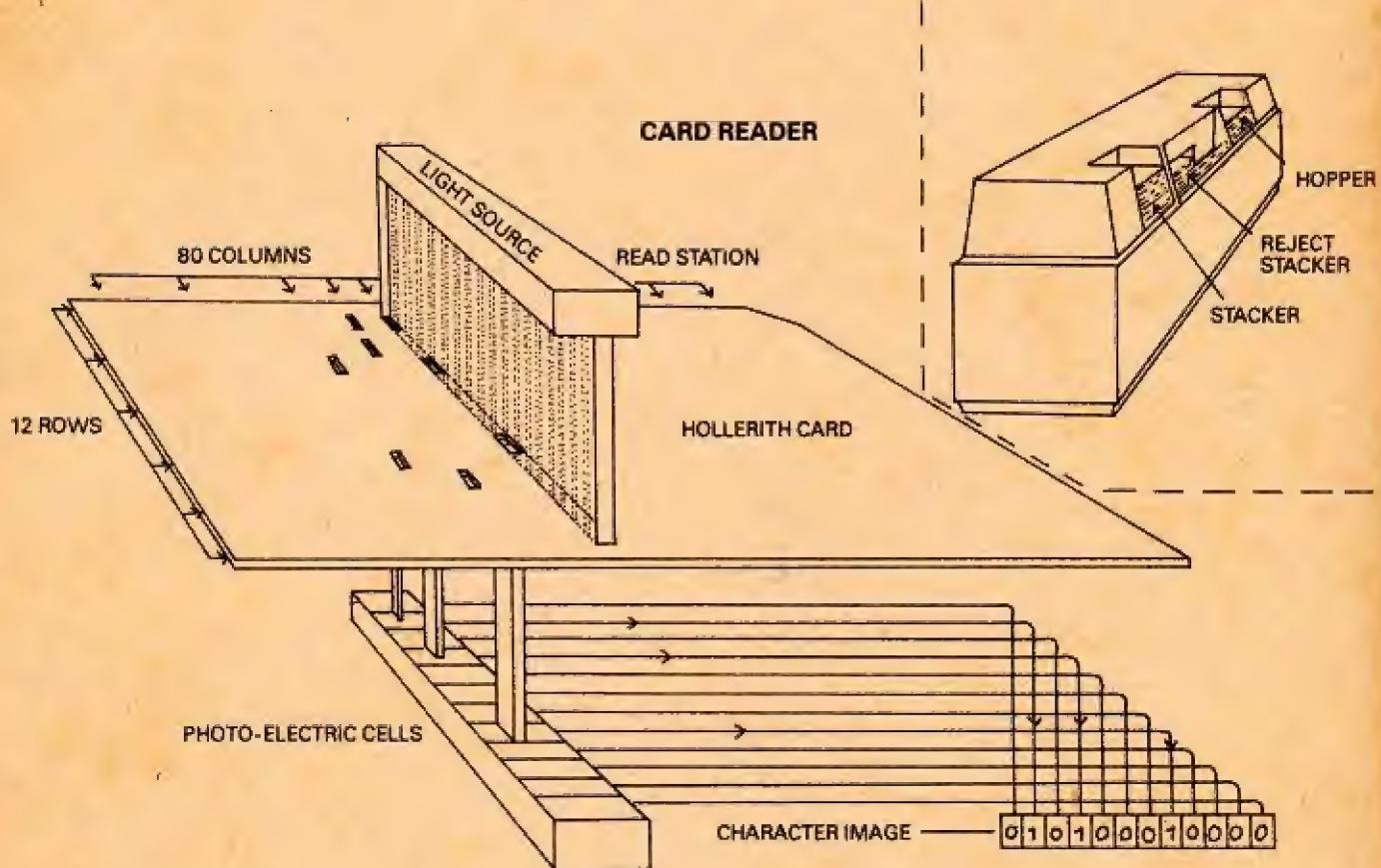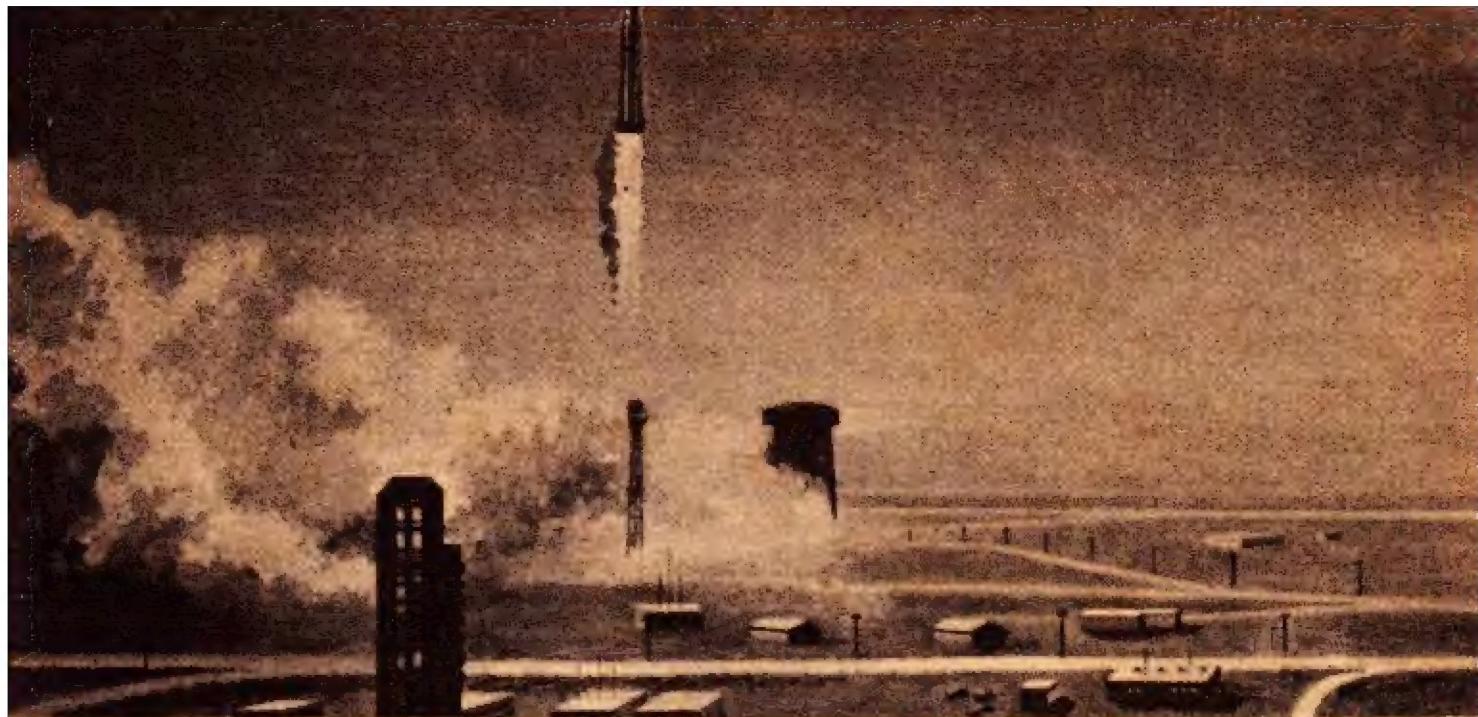
All systems "go" was the command given by the computers for the launching of the astronauts.

vast chain of binary digits can be expressed and tabulated at very, very great speeds.

The binary numerals can also represent logical conditions such as "yes" (binary 1) or "no" (binary 0), "right" (binary 1) or "wrong" (binary 0). Hence, the modern computer, by using the binary, can make simple decisions about complex questions. For example, in Colonel Glenn's manned orbital flight, it was a computer that gave the "go" signal that everything was fine aboard during the launching of the space capsule.

For the computer to reach this all-important logical decision, the programmer fed into the machine beforehand such information as the proper speed and direction of the rocket, desired flight characteristics, Glenn's proper breathing and heartbeat rate, plus over 40,000 other bits of vital data. This information was stored in the memory element. Then when the actual launching took place, all the information from the rocket and about the astronaut's condition were fed into the computer and compared with the data already stored there. In less than 30 seconds, the computer had to make its recommendation. No man or group of men could make this important decision so fast, but the computer gave its answer by simply causing a bulb to light up on its front panel, signalling, "Yes, all conditions are fulfilled for a safe launching of the space capsule."

Can machines out-think the men who build them? Is it possible for a computer to come up with a new idea? Are we in danger of being overrun by electronic brains whose actions may not do as we wish?

Can an electronic brain "think?"

If you build the computer described earlier, you will see that it operates only

25

on information you give it. Computers can not "think." They do no more than you tell them to do. If you feed yours incorrect information, it will give you incorrect answers. In addition, you must tell it exactly what to do, step by step. Bluntly, a computer does not have an ounce of imagination.

As you have read earlier, a programmer

How are problems given to a computer?

must organize and restate the problem in terms that a computer can understand. One technique used by programmers is to prepare *flow* or *block diagrams*. These diagrams arrange the steps of a process in order and show how the steps are related to one another. They aid memory and force precise thinking. They show the computer how to solve a problem.

For instance, how do you get to school in the morning? A flow diagram of this problem might be the one given in Fig. 1. This may be enough for you, but it is not detailed enough for a computer. Your mind makes connections readily. It fills in gaps from past experience. Computers need a simple, step-by-step plan with complete instructions, such as shown here in Fig. 2.

Programmers also use many mathematical techniques. One method, *symbolic logic*, involves representing statements logically by mathematical equations. This system makes it possible to change logical statements in the same way that you work with algebraic equations in your mathematics class. It is named *Boolean Algebra* after its inventor, George Boole. Computer men also use the *theory of probability* and complicated techniques such as *Monte Carlo simulation, matrix algebra,* and *multiple regression*. These complex mathematical solutions are too difficult to explain in this book. As a matter of fact, many mathematicians did not use them prior to the introduction of computers because of the time required to solve problems by following these techniques.

Programmers sometimes develop mathematical models of real situations or processes. Here is an extremely simple example:

COST OF APPLES IN PENCE =

2p. X NUMBER OF APPLES

This equation is a "model" of an actual buying situation. It predicts the cost of any number of apples. No apples need ever be purchased in order to get answers. All aspects of this limited situation can be explored without spending a penny.

In actual practice, the preparation of mathematical models is a complex, exacting, and time-consuming job. It requires a thorough knowledge and understanding of the problem or process under study. Programmers often spend weeks, even months, observing and studying before they begin the mathematical model for which a final programme will be prepared.

| GET UP	GET READY	GO

A flow diagram of "How do you get to school in the morning?" as stated above would be enough for you, but not for the machine. The flow diagram on page 27 would be more to the machine's "liking."

HOW TO GET TO SCHOOL IN THE MORNING
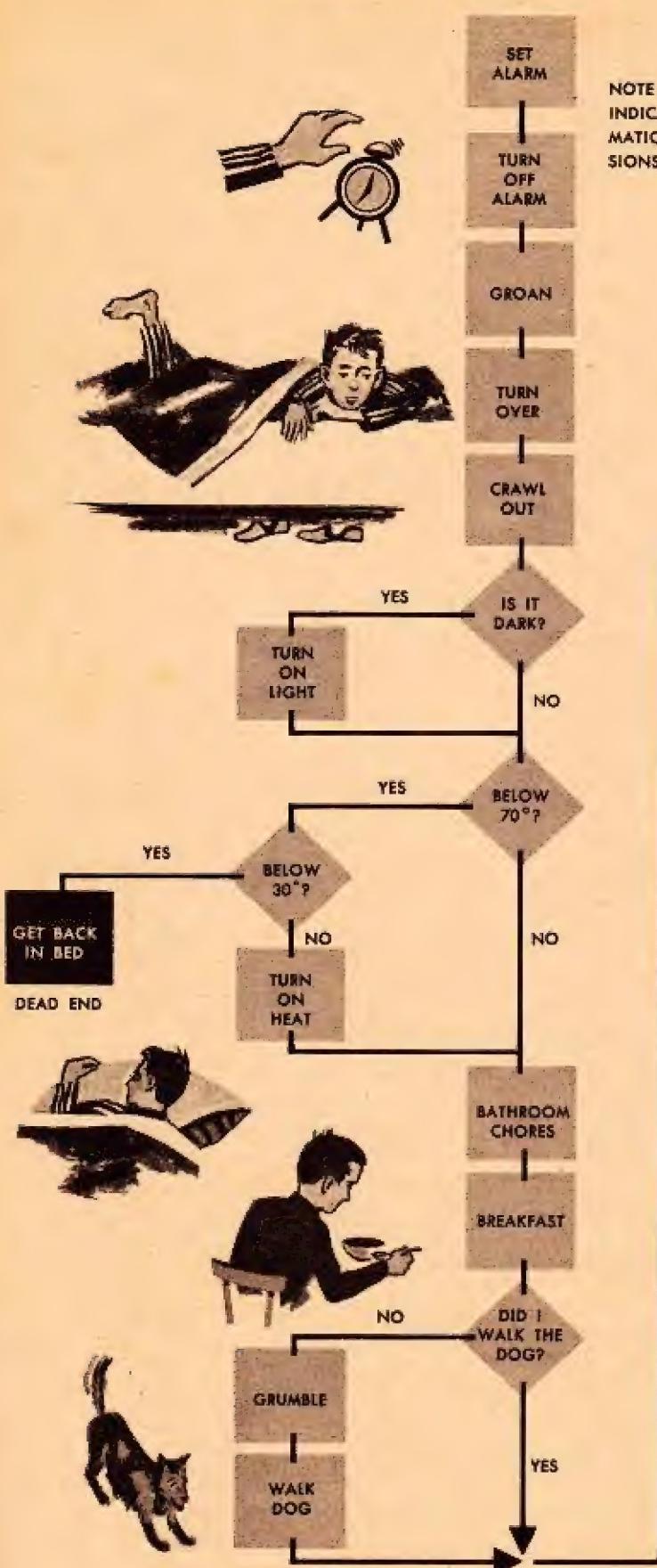
NOTE THAT IN THIS DIAGRAM RECTANGLES ARE USED TO INDICATE EITHER CALCULATIONS OR THE TRANSFER OF INFORMATION. DIAMONDS ARE USED FOR SIMPLE YES–NO DECISIONS. INSTRUCTIONS FOR THE MACHINE ARE ALSO INCLUDED.

SET ALARM

TURN OFF ALARM

GROAN

TURN OVER

CRAWL OUT

IS IT DARK?
YES → TURN ON LIGHT
NO

BELOW 70°?
YES → BELOW 30°?
YES → GET BACK IN BED — DEAD END
NO → TURN ON HEAT
NO

BATHROOM CHORES

BREAKFAST

DID I WALK THE DOG?
NO → GRUMBLE → WALK DOG
YES

HAVING TEST TODAY?
NO
YES → PRETEND ILLNESS

CONVINCE MOTHER?
NO
YES → GET BACK IN BED — DEAD END

WALK OUT DOOR

FORGET BOOKS?
YES → GO BACK GET BOOKS
NO

GET ON SCHOOL BUS

ARRIVE AT SCHOOL

27

No one can give you a good answer to this question.

The profession is so new, and is changing so fast, that the most practical approach is to look at what a programmer must be.

First, he must be a language expert. The languages he uses are not all spoken languages like English, French, or Spanish. Some are universal languages, understood by scientists and technical people the world over. These are mathematics and the language of reasoning or logic. Maybe you do not think of mathematics as a language, but it is. It is one means used by men of science to communicate with each other.

A programmer must know many languages:

1. His native tongue.
2. The language of the flow or block diagram.
3. The language of logic or reason.
4. The languages of the specific computer with which he is working. This includes the codes of letters, binary digits, or combinations of them.

DECOYS

MISSILE PATH

RECEIVER AND COMPUTER

RADAR SPOTS . DECOYS

DETECTION STATION

In addition, the programmer must be able to study, analyze, and plan problems so that he can reduce them into the small, simple parts a computer can handle. Thus, a person with an economic or engineering college degree or a background in mathematics may be the most successful candidate for a career in computer programming.

Putting the Computer to Work

Though computers have been in use for only a decade or so, they have already influenced the lives of millions of people. It would be impossible to list all the jobs that we are handing over to this marvellous machine. Programmers are finding new applications for it each day. While many uses have already been given, here are a few more ways to keep robots with electronic brains busy.

BATTERY CONTROL COMPUTER

NIKE-ZEUS RADAR

NIKE-ZEUS LAUNCH

human being could possibly work with the speed and accuracy required by this complex operation.
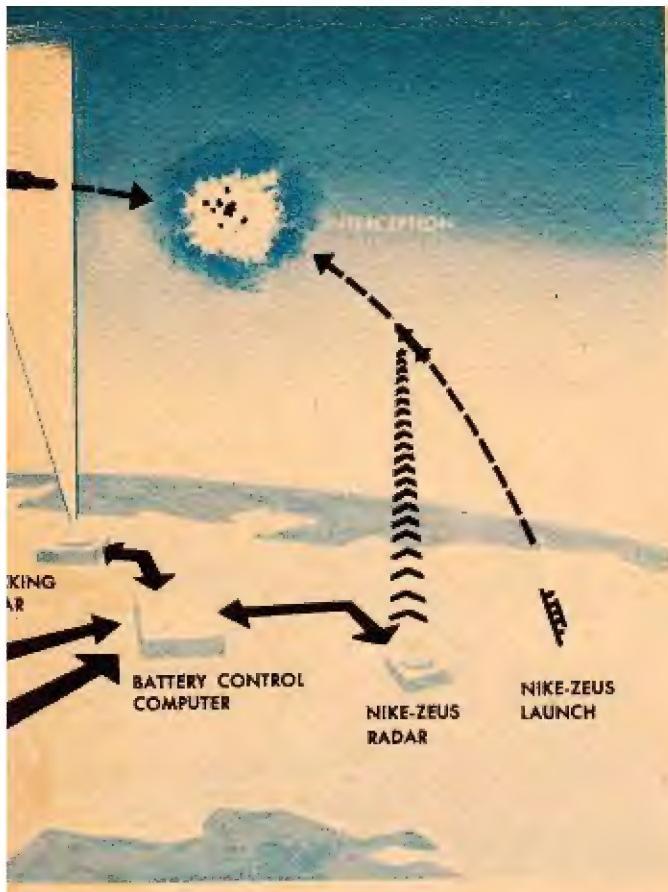
Computers are also the "heart element" of the North American Air Defense Command. These computers evaluate the great amount of information represented by the flight paths of all the airplanes in the air at one time over the United States and Canada. Working hand in hand with the radar system, they keep the military services informed by immediately identifying all planes and rockets that are in flight. This, of course, reduces the chances of an attack by hostile aircraft and rockets.

Computers are the "brains" of the American defence system. A ballistics missile in flight, for example, must be in exactly the right position at the proper speed when its motor is turned off — an error of one foot per second in speed can cause a several mile miss at the point of impact. As the missile leaves its launching pad, it sends radio signals back to the computer on the ground, informing it about changes in wind, temperature, effect of gravity, and many more important facts. The computer works out the effect of these varying factors and instantly flashes instructions to keep the missile on its proper course. When it reaches its correct speed, the computer turns off the motor and the missile coasts at about miles an hour to its target. No

How are computers valuable for national defence?
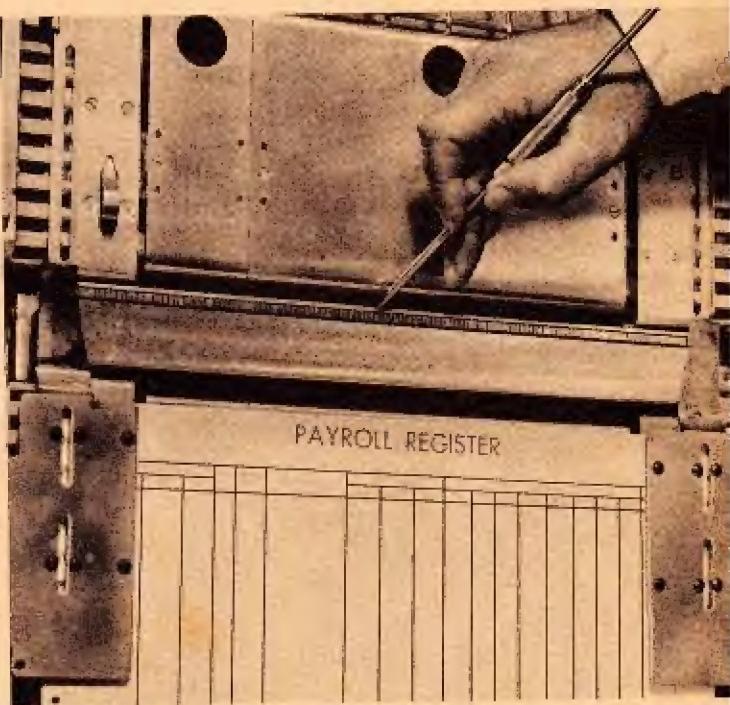
Computers for payroll register: This horizontal row of 132 electronically timed hammers taps paper-forms against an inked ribbon and a fast-moving endless chain of type in an output printer of a data processing system. It prints numbers and letters at a basic speed of 600 lines a minute and, if it is operated to print numbers alone, can do it at a rate of 1,285 lines a minute.

29

Computers perform numerous jobs in the field of business. They have freed employees from the drudgery of the routine paper work of accounting, invoicing, calculating the taxes, making out pay cheques, keeping inventories, etc. Publishing companies use computers to keep track of magazine subscriptions.

How do business and industry use computers?

Business and industry also use computers to help in making decisions. For example, an oil company deciding where to build service stations, can feed a computer all the factors involved in the decision, such as traffic flow, land and building costs. The machine will produce a decision or the alternate decisions most worthy of investigation.

Computers are keeping track of thousands of ships in the Atlantic and Pacific oceans so that the various rescue services can rush

How are computers used to aid sea and air travel?

help instantly if a ship is in distress. Ship positions are stored on the machines' memory sections, enabling the rescue services to select the vessels nearest an emergency without changing the courses of other ships unnecessarily.

To assist with the planning of airline flights, a computer prepares what might be called "a master flight plan" for each flight. Weather information, information as to the number of passengers, fuel loads, take-off and landing weights, and other data are fed into the machine. The computer then analyzes all data and calculates the ideal routes, altitudes, etc., in the terms of these conditions. In this way pilots have a "master plan" to follow in their final flight planning. Using this information, the airline's captain and dispatcher determine the "final plan."

Computers are also being installed in some of our giant jet aircraft. With the use of such planes, the margin of safety available to a pilot during a take-off has been decreased greatly. The amount

Computers handle numerous jobs to ease the drudgery of officework, in aiding the safety of sea and air travel, and in giving help to the medical science and other fields.

of power and the increased speed requirements of take-off have greatly reduced the time available for the pilot to study his take-off progress and to make his decisions. Thus, the computer on board, with its lightning action, can be very valuable to the pilot during this critical operation.

Computers will be used in many ways in hospitals. They could store all medical knowledge and make it available to doctors on demand. Symptoms of known diseases could be held in the computer memory. A doctor could input the symptoms of his patient using a videoscope, the computer would then check and list the possible diseases matching the given symptoms, thus helping the doctor's memory.

How can computers help our doctors?

Another possibility would be in patient monitoring. Suppose we have a very sick patient and that it is essential that his temperature does not exceed 104F. and his blood pressure 170. A

Would you believe it, when you saw it in a science fiction picture? The data transmission unit above enables computers to hold direct two-way telegraph or telephone "conversations." Or, to put it a little more specifically: the computer can send business or scientific information any distance directly from its magnetic memory to the storage of another computer. Here the operator dials the office across the country to make a connection for data transmission.
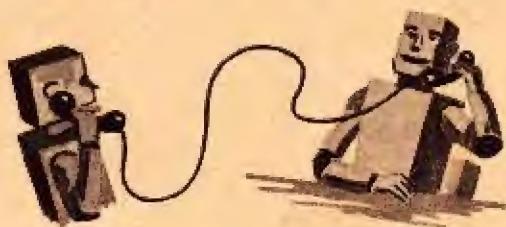
nurse could check every hour but what if a limit was exceeded when the nurse was away? The patient could die. To stop this, devices for measuring blood pressure and temperature could be attached to the patient and the computer. Continuous signals could be sent to the computer giving these measurements. If a limit was exceeded the computer could activate an alarm bell in the nurse's office which would be of great help in her job.

Each year, millions of reports on scientific research are published—a large percentage of them in foreign languages. In this mass of Russian, German, Dutch, and Italian data are clues to interplanetary flight, H-power, longer-wearing car tyres, more powerful batteries. The trouble is that too few of our scientists and engineers read foreign languages. To overcome this difficulty, computers have been put to work translating these scientific publications.

How does a computer become a translator?

To do translations, every word in a sizable English dictionary is listed on tape under a code number or address. The French, German, or Russian equivalents for each word are given the same number or address. Then, to translate from French to English, for example, a tape with the French code numbers is fed into the machine, which matches the numbers and prints out the English. Some human editing to rearrange awkward word sequences is needed, but a

The electronic brains have made another dent in the "language barrier." Here (at left) sentences in Russian are punched into cards that will be fed into an electronic data processing machine for translation into English.

The card (below) is punched with a sample Russian language sentence (as interpreted at the top of the card) in standard punched-card code. It is then accepted by the computer, converted into its own binary language and translated by means of stored dictionary programmes into the English language equivalent, which is then printed.

KACHYESTVO	UGLYA	OPRYEDYELYAYETSYA	KALORIYNOSTJYU

| THE QUALITY OF COAL IS DETERMINED BY |
| CALORY CONTENT |
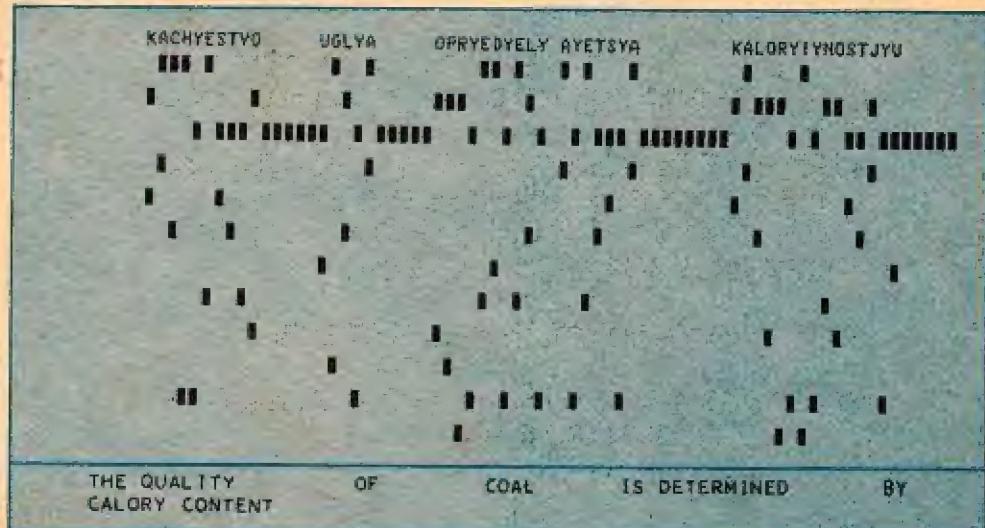
Above, specimen punched-card and, below it, a strip with translation.
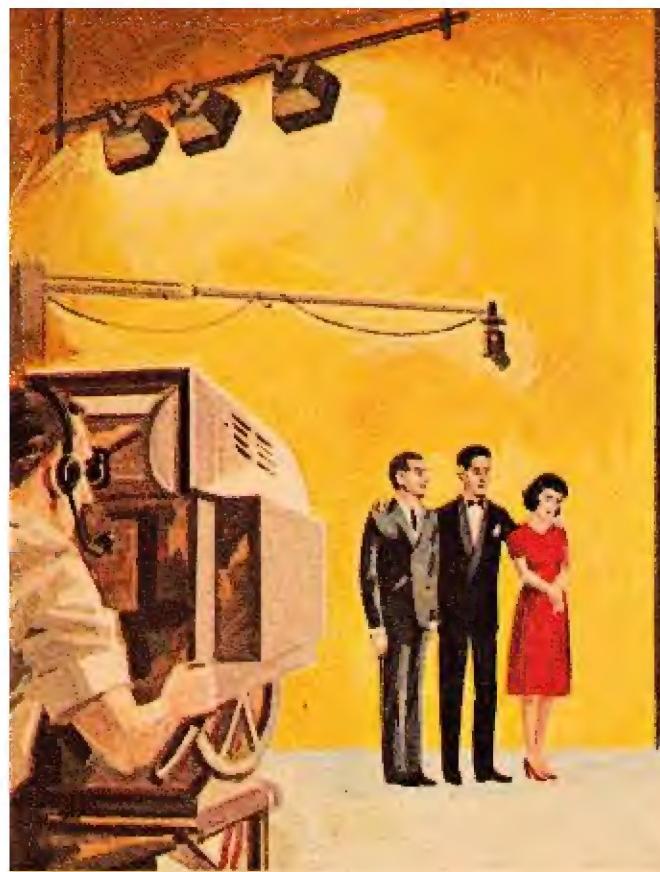
The match made by a computer on a television program was not one of the "robots" big successes.

computer can make over a thousand translations in a day.

Computers are helping to break language barriers in other ways. Computers, for example, are rapidly translating English text into Braille in order to speed the production of reading material for the blind. Recently, an extremely accurate and thorough *Biblical Concordance* was produced by a computer, which "read" the whole *Bible* through, sorted and cross-indexed selected key words, and printed out the results automatically — an entire book written by the computing system.

A computer, of course, gives wrong answers if given

Does an electronic brain ever fail?

wrong information. One experiment with the decision-making ability of computers was a failure. A television quiz programme used a computer to select the ideal wife for a contestant. To accomplish this, the programmer fed into the machine all facts known for a perfect marriage—likes and dislikes, interests in various hobbies, films, music, food, etc. When the computer compared the qualifications of many women with those of the male contestant, it recommended one as ideal. But, when the two got to know each other, they decided they were mismatched and should not marry each other. Whose fault was this? The machine programmer's? Perhaps it only proves that even a computer cannot understand a woman's mind.
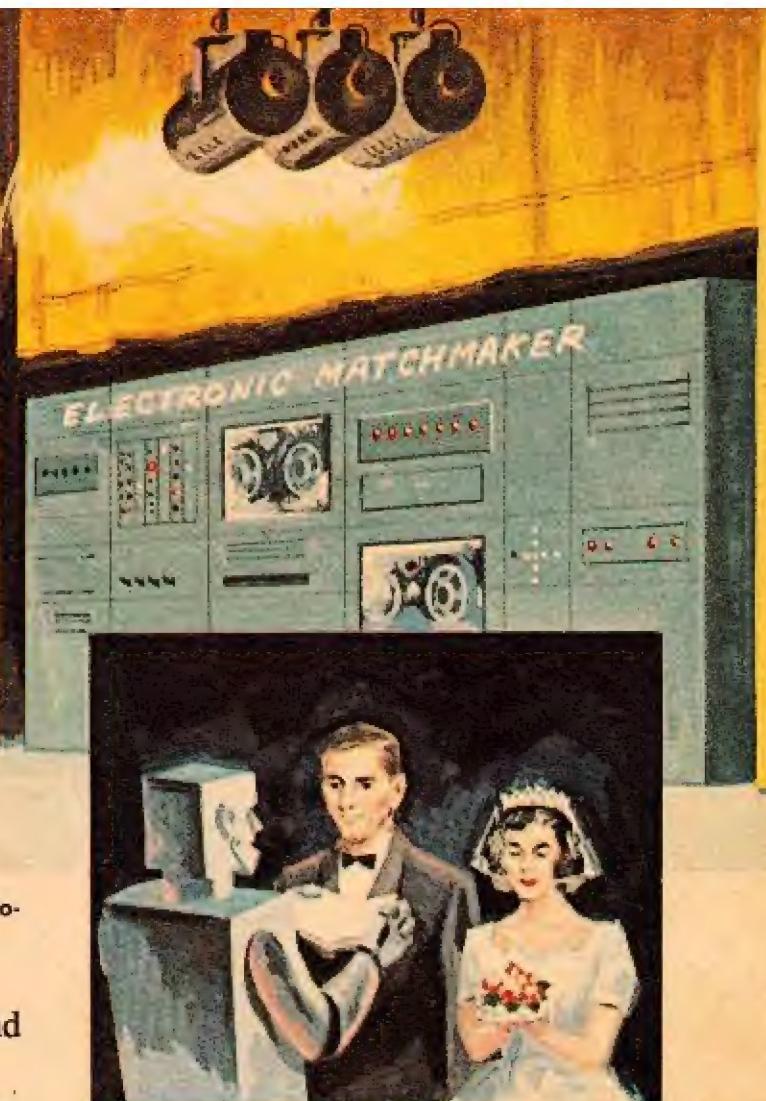
The Learning Machine

A science fiction story of some years back concerned a robot that revolted against its human masters and refused to work. The reason, eventually discovered, was that the machine did not like being turned off each night — in effect, killed — as a reward for its hard day's labours. So after that, the electric wall plug was left in all the time and both the robot and men hummed along merrily forever after.

Can a robot learn?

As you have read, there is no machine that can "think." But, there are robots that are capable of learning. Learning, as we know it, is the process by which knowledge or a skill is acquired, a process which requires attention and direction of efforts. It is often a trial-and-error method. A teacher can speed up the learning process by directing the learning effort and thereby decreasing the number of trials. The learning machine matches many of the characteristics exhibited by the human learning process. For instance, the learning process in man is known to require repetition in order to effect the storage of new ideas. Remember when you learned the alphabet? You did so by repeating A, B, C, D, E, F . . . time and time again until you learned the complete alphabet correctly. This procedure of repetition is necessary for the learning machine to "learn," too.

How does the learning machine "learn?"

The learning robot is not a computer and is not designed to work on speedy calculations or work logically from step-by-step formulas fed in by programmers. Instead, it tackles problems for which no formula is known. It works out its own method of
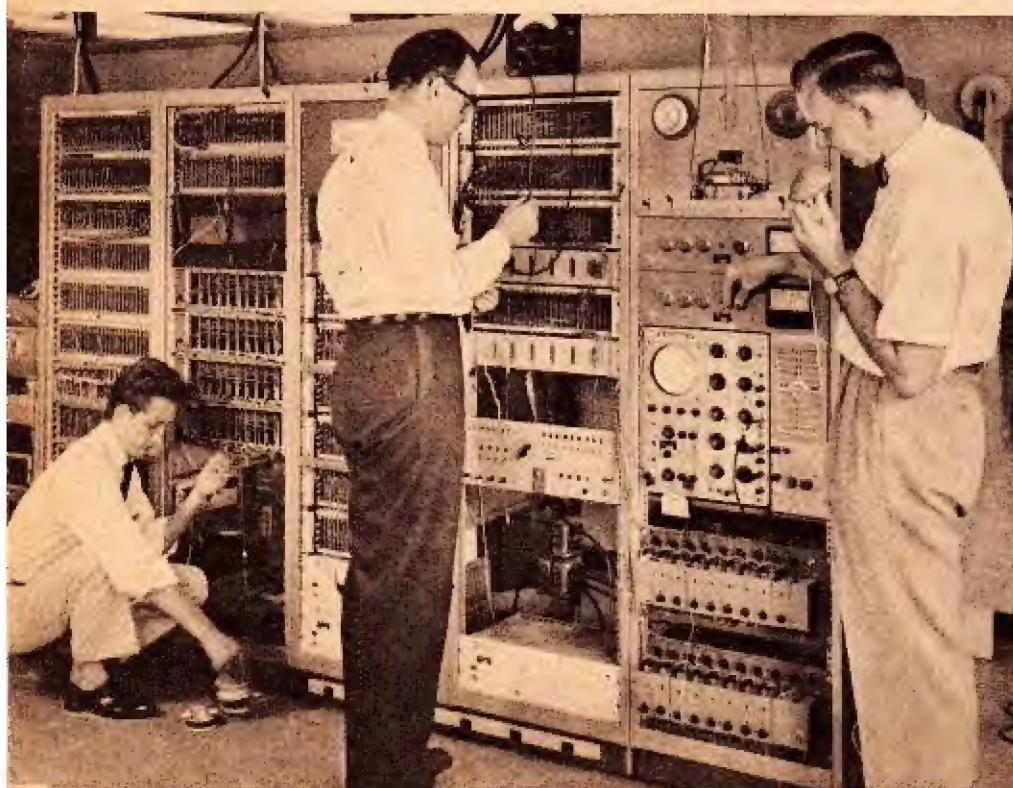
The "robot-secretary" — the computer at left is designed to recognize all American speech sounds and, when spoken to through a microphone, type out what it has "heard."
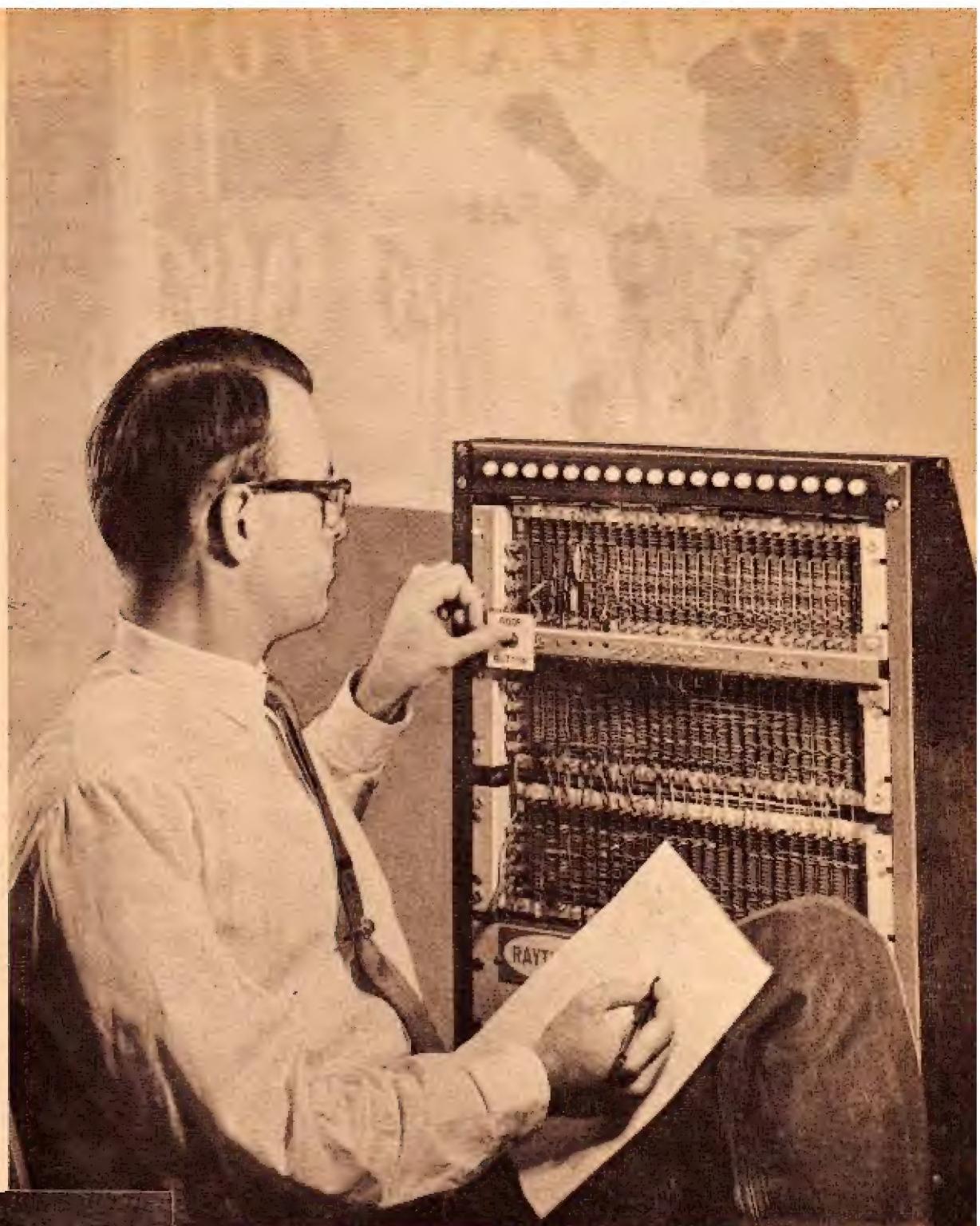
The learning machine above, if it does not catch on to new lessons, has its "goof" button pushed for "punishment." This causes the machine to re-evaluate decisions and change the "memory." The tapes in the background contain lessons on various subjects, including the quite complicated analysis of sonar and cardiograms.

attack, supplies the answer, and can explain how it arrived at the answer.

The learning machine works by trial and error. Like a human, it relates new situations to its past "experiences," getting cleverer all the time in problem solving. Also like people, it learns through pain and pleasure. (When you were younger, you learned by experience not to touch a hot stove by the "pain" of a burn and learned the reward of doing something correctly by the "pleasure" of receiving sweets or being praised.) When the machine makes a mistake, its human teacher pushes a "goof" button, forcing it to do the problem over. As a "reward," it is allowed to operate uninterrupted.
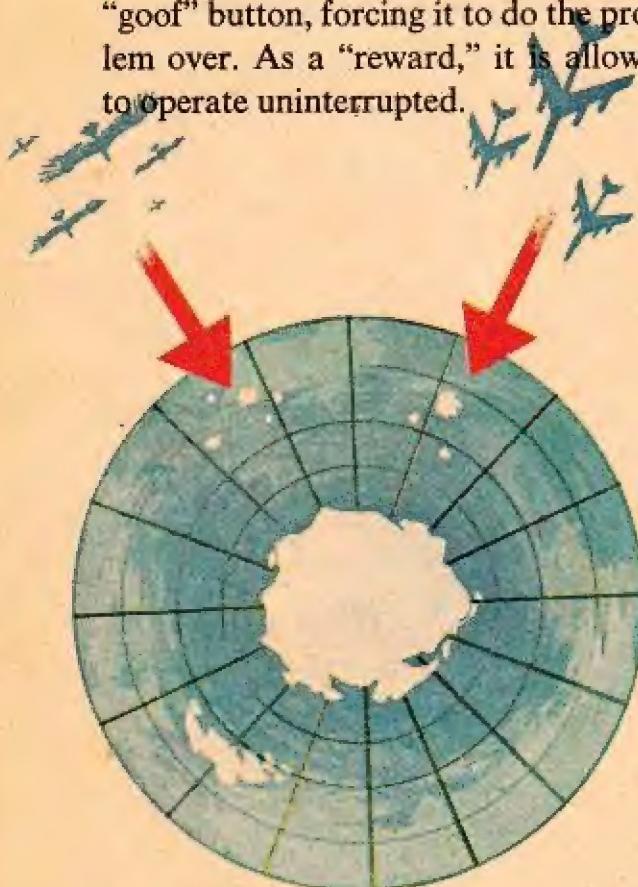
While it is difficult for a human operator to distinguish between the blips caused by an airplane and those caused by birds, the learning machine, when once taught, will function flawlessly.
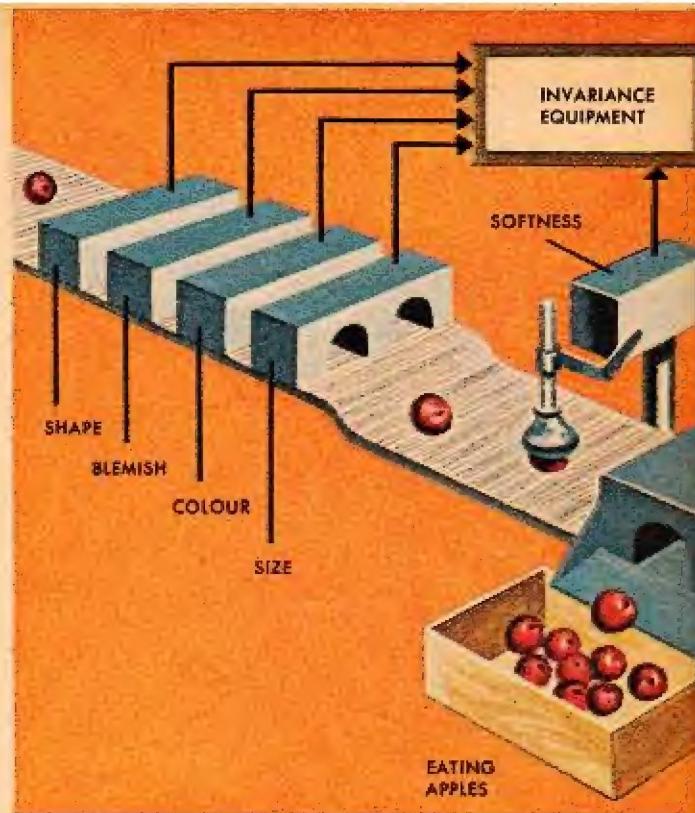
The learning machine has proved its worth in analyzing cardiograms —electronic tracings of heartbeats — and radar echoes. In the latter example, a critical problem is the need to train radar operators to tell the difference between true target echoes and false ones. Thus, a coastal defence radar station needs to be able to distinguish instantly an enemy plane or rocket from a flock of homecoming seagulls. Normally it takes months for a human to acquire the skill to tell what the different "blips" on the radar screen mean. But the learning machine can be taught the job in a very brief time and will perform like a veteran.

How are learning machines used?

A very simple application for this robot would be to teach it to sort apples. First, the machine would be taught in much the same way as the beginning apple sorter just hired. The drawing on this page shows the parts of the device.

GOOF BUTTON

EXPERT TEACHER

MEMORY

ASSOCIATION UNIT

DECISION

CYBERTRON (LEARNING UNIT)

THRESHOLD

SAUCE APPLES
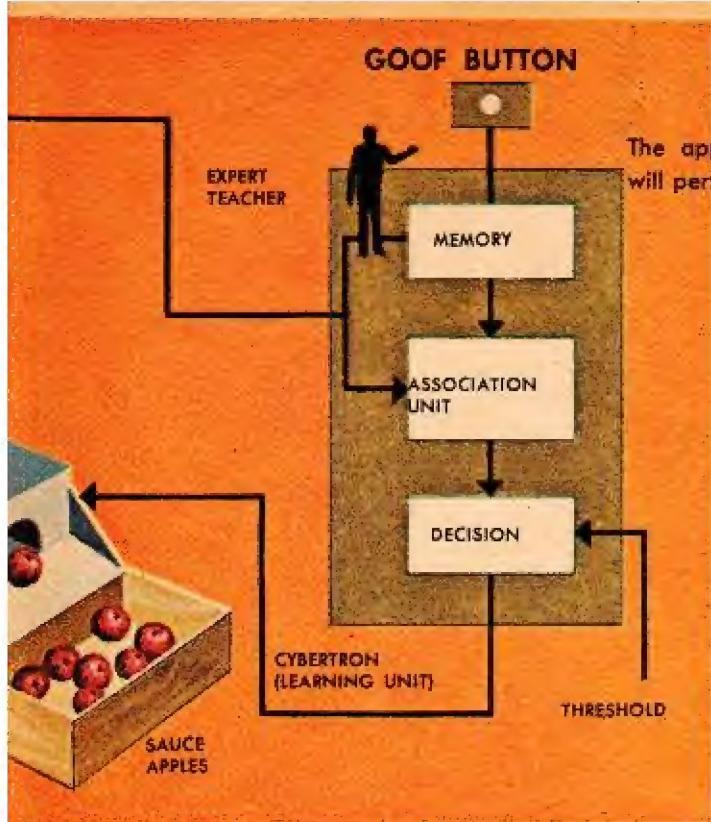
The apple-sorting machine, once properly taught, will perform to utter perfection.

The apples pass by the *scanners* (they work much like television cameras) on a moving belt where the information as to redness, softness, size, etc., is changed into electrical signals that are fed into an *invariance unit* whose job it is to arrange these signals and information. (The invariance unit is used, where possible, to lessen the data handling load of the learning machine.) The apples are to be sorted into those for eating and those for apple sauce. As each apple is scanned, the learning machine takes action and dumps it either into the "eating" or "sauce" bins.

An expert apple sorter in this case is a "teacher" until the robot learns his lessons well. Every time the machine makes a mistake he presses the "goof" button and the machine has to change its "memory" slightly to take that fact into consideration and correct its future action. After each error, the machine gets a little better at the task of sorting apples and after a short time becomes almost perfect. The learning machine has many other uses in factories, too.

The Teaching Machine

Machines play chess, compose beautiful music, do difficult mathematical problems, and have shown that they can learn from experience. We also have machines that teach. At first these teaching machines were built especially for the purpose, now we can use the computer for linking videoscopes in the classrooms to a central computer. In Chicago there are over 100 videoscopes located in seven schools linked to the central computer. In the Bronx, New York City, there is even a robot called LEUCHIM helping out.

If your school does not already have teaching machines, you may not have

What does a teaching machine look like?

seen one. These robots are rather simple looking and quite harmless. In most

THE TEACHING MACHINE (TMI-GROLIER'S MIN./MAX.)

cases, they are just metal or plastic boxes with two windows in them, and a few knobs or pushbuttons here and there.

To operate most teaching machines, you press a button and it brings your first question into view in one of the windows. Then you write your answer on the paper exposed by a small window near the top of the machine. When you press the button again to get the correct answer, a shield covers your answer, making it impossible to change it.

Now, press the button again to get your next question. As it appears, your answer to the previous question slides out of view, the shield disappears, and

you have a clean paper area to write on again.

The teaching machine teaches you your **How does a teaching machine "teach?"** lessons in the same way we teach a machine to learn. The programmer (your teacher) puts a programme (your lesson) into the machine (the input) and you (like the computer) process the material. You study the question, reach into your memory element, and come out with the correct answer — you hope. This, like the computer, is your output.

By having the lesson fed to you rather slowly and well-planned, you learn by trial and error, just like a machine. If you make a mistake, the teacher pushes the "goof" button, but, unlike a machine, your punishment may be to stay after school.

The square of 4 is: 4 times 4 or 16
The square of 6 is: 6 times 6 or ___?

36
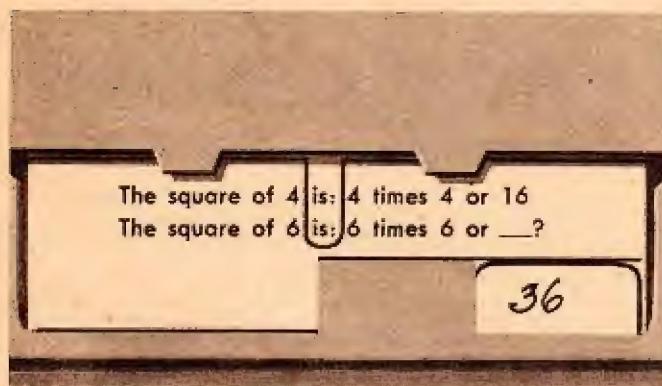
Close-up of the part of the teaching machine that contains the question and at the lower righthand corner your answer. On the illustration below it you see the next question and your check of the answer for the previous one.

36   *36*

The square of 9 is 81
The square of 8 is ___?
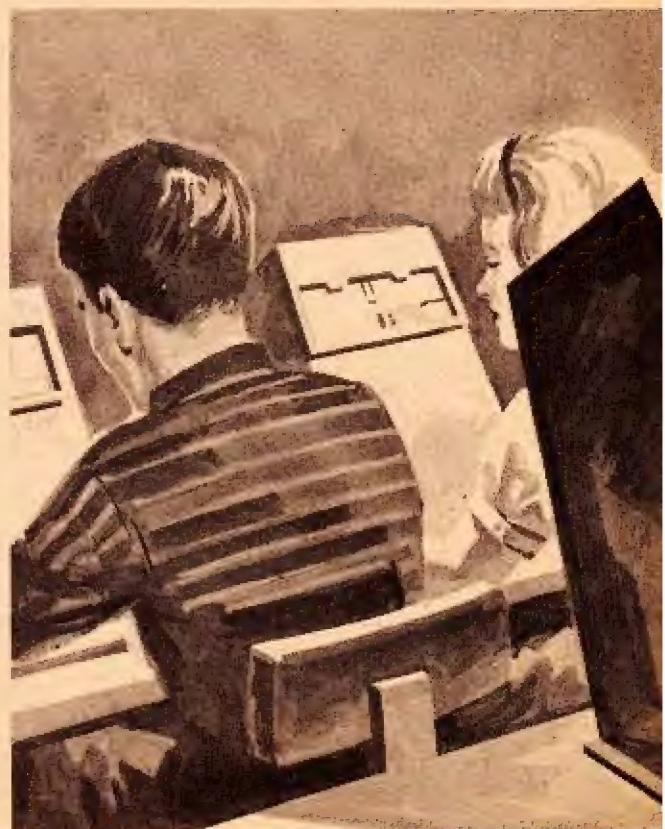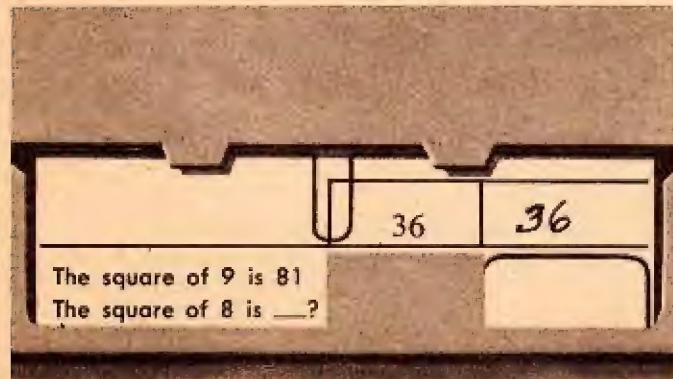
Teaching machines will not replace teachers. But, *programmed learning*, as this type of teaching is called, will help the teacher to teach better. These machines will also help to solve the teacher shortage by allowing larger classes. Since pupils using these devices require little supervision from the teacher, she has more time to give special help or to do other classroom tasks.

Can machines replace teachers?

We can also use the computer as a teaching machine. This is called CAI or Computer Aided Instruction. Instead of a teaching machine we use a videoscope. The computer can hold a wide variety of teaching material and make it available to pupils in several classes at once. It can also keep a record of how well you are doing and let the teacher have a note of it. In this way it will help the teacher even more than the teaching machine.

Robots Take Over

Robots and computers, as we have seen, are taking over more and more jobs formerly done by man. True, men can still do everything that these machines can do. But it takes a thousand men working a lifetime to compute what the latest electronic brain can do in a day.

No book on robots and computers would be complete without mentioning the word *automation*. Generally speaking, this term refers to a combination of machines and electronic devices that handle certain rapid services or the mass production of goods. Because modern computers are self-regulating, they can be used to control assembly-line production electronically. They can also be used to perform other factory jobs and run machinery.

What is automation?

To have automation, we must have machines and processes that regulate themselves. To do this, *feedback* is needed. Feedback provides a means by

What is feedback?
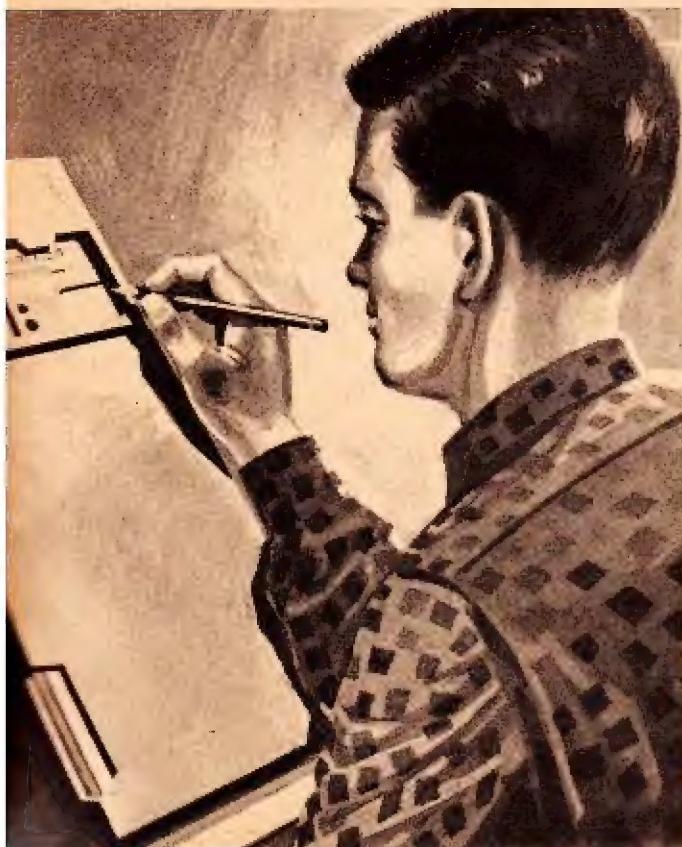
The working of the thermostat is a typical example of closed control, or an operation with feedback. The three components HEATING — ROOM TEMPERATURE — THERMOSTAT are connected in such a way, that any change in one component causes a change in the other component. You will easily understand how important this is if you visualize the same example with no feedback, with open control: You could have a circuit where the outside temperature causes the start and closing of the boiler. In this case, the thermometer outside "informs" the thermostat of the temperature. The thermostat just as before, will start the boiler when the outside temperature reaches a certain point, and it will turn off the boiler when the outside temperature has reached a certain degree above the starting point. The actual room temperature however, will not be fed back to the thermostat. This means: If it is cold outside for a few weeks, the boiler will work, even if you are roasting in the room.

CLOSED CONTROL

THERMOSTAT

ROOM
TEMPERATURE

FURNACE

OPEN CONTROL

OUTDOOR
TEMPERATURE

THERMOSTAT

ROOM
TEMPERATURE

FURNACE
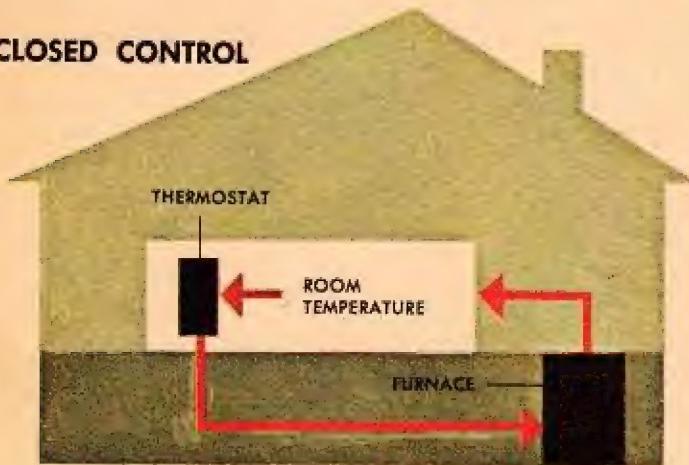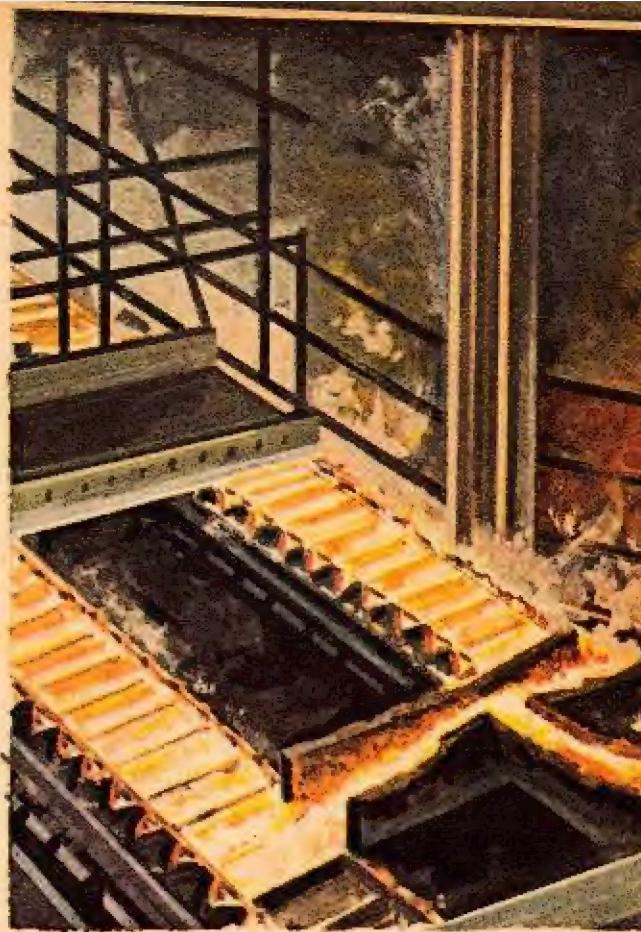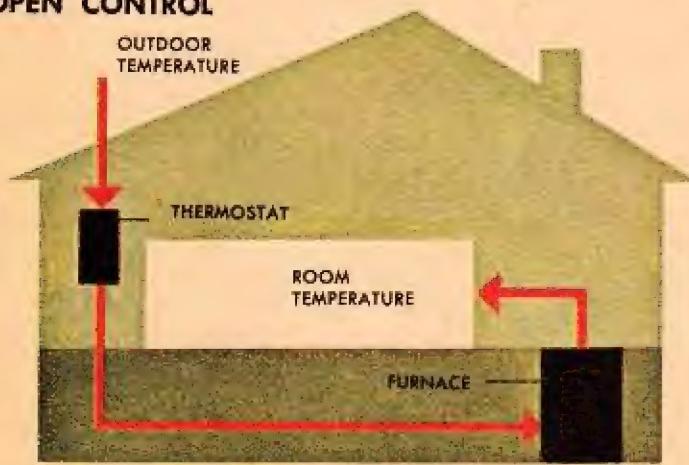
which information concerning a machine's operation is continuously fed back to the machine and compared with the desired results.

One feedback device that we all are familiar with is the thermostat found in home heating systems. Let us assume that the thermostat is set at 72 degrees. When the temperature in the room is lower than 72 degrees, the thermostat feeds back this information to the boiler. The boiler then turns on automatically. It remains on until the thermostat feeds back the information that the room temperature has reached 72 degrees. This turns the boiler off. Since this process goes on continuously, it is called *closed control*. Today, the electronic computer is the "brains" of most automation operations. It feeds back information to the machines that
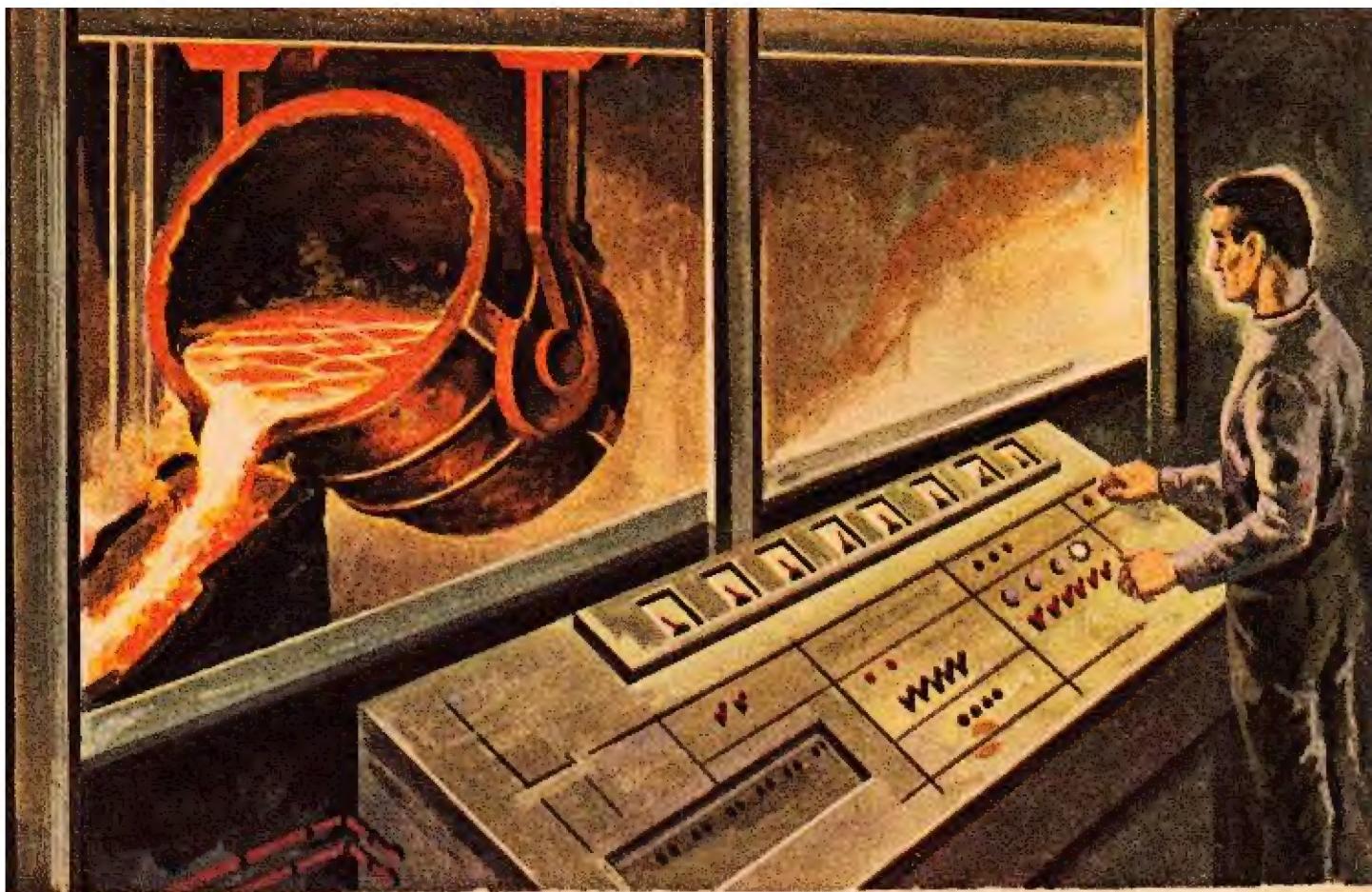
do the work just as the thermostat feeds back the temperature data to the boiler in our heating systems.

While automation may do away with

Does automation put people out of work?

many unskilled or semi-skilled jobs, it will provide many new work opportunities. The age of automation will need highly trained workers who can maintain and repair automatic machines. It will also make new professions

We use the word "thermostat" so easily, and we talk about how intricate its operations are, but do you know how it actually works? — It is a thermometer of sorts in the first place. Based on the fact that different metals expand and contract at different temperatures, most thermostats have, as the illustration shows you, a curved metal strip which consists of copper on one side and chromium steel on the other side. The strip curls over in one direction when the temperature rises, and in the

other direction when the temperature falls, because of the fact that copper and steel react differently to the change of temperature. The curling in one direction will close a circuit and throw a switch that will start the boiler. The moving in the other direction will break the circuit and throw the switch to stop the boiler.

COPPER

CHROMIUM

41

such as computer operators and programmers. Industry forecasters predict that by 1982 the computer industry will be the third largest after petrochemicals and automobiles.

The era of robots and electronic brains, like the machine age before it, should bring increased leisure and higher standards of living for all. This means more people will be needed as teachers, librarians, hotel keepers, road builders. How can you prepare for these far-reaching effects? The answer is not new. The answer is to stay in school as long as you can and learn as much as possible while you are there.

Automation in Action

In our world of speed and advanced technology, automation is no longer just the most modern or money-saving way to do a job. In many instances, it is fast becoming the only practical way that jobs can be done.

Computers and robots' mechanical hands are essential to our country's telephone communication system. In former times, it was necessary to place telephone calls with an operator who, in turn, had to contact the person you were calling. This sometimes took a great deal of time. But now, with the help of these machines, a large number of British telephone subscribers can dial long distance numbers directly. Message accounting tapes make it possible to record automatically the time of a call, how long it lasted, the calling number and the number called.

How is automation used in communications?

Without automation, our telephone system would probably break down. Even if the Post Office could find enough operators—and they probably could not—the cost of a phone would be so high that most families could not afford one.

Other forms of communication such as radio are using automation devices to speed up their services. The Post Office is increasing the installation of machines to handle the millions of letters which are posted every day.

If you travel a great deal you know that automation is being used increasingly. The airlines have automated seat reservation systems using computers. You go in and ask for a reservation. The sales clerk does not look at a list but types out your requirement onto a videoscope. The message goes down the line to a computer which looks up the flight that you require in its records. If there is a seat available, it will send a message back saying O.K. but if not then it looks up the nearest flight and tells the

How is automation used in transportation?

The first subway train without a driver had its tryout not long ago in New York City.

"PLEASE RESERVE TWO SEATS . . . ."

"RESERVATION CONFIRMED!"
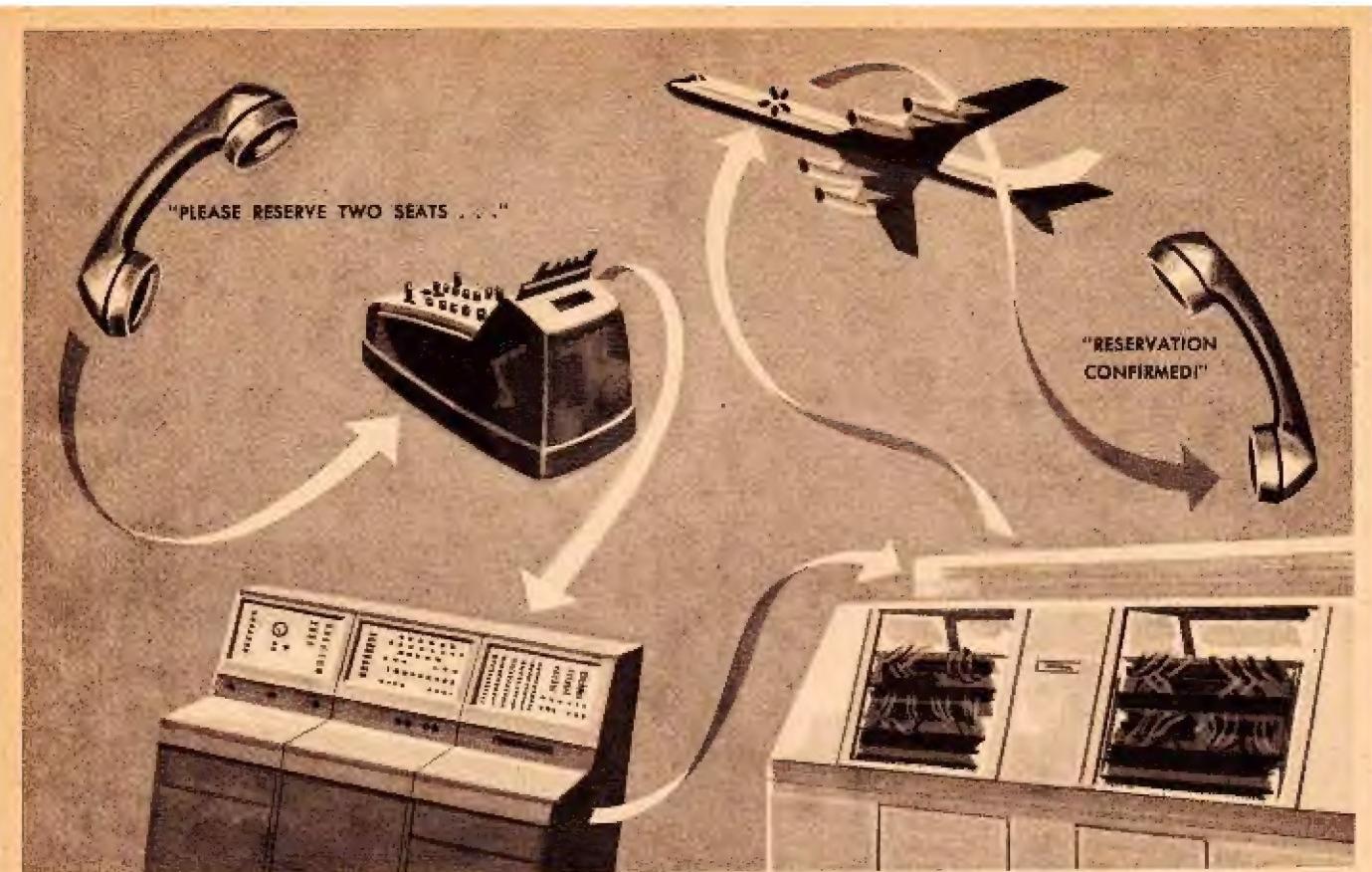
American Airlines Magnetronic Reservisor enables the reservation agent to obtain immediately all data on requested flight reservations and even a number of possibilities for alternate suggestions.

sales clerk who will then offer you this. If you agree, then the clerk asks for your name, address and other details and types them out on the videoscope. When he has typed them all out he presses the 'send' key and the information is sent down the wires and entered in the customer record file in the computer memory.

In the same way steamship and railway companies are using computers to look after their seat reservations. The big advantage for these companies is that their records are always completely up to date, in fact right up to the minute that you stand and ask for your reservation. Many railways are using computers for controlling their freight reservations and in this way they become more efficient and offer their customers a better service.

Automatic controls have largely replaced men in various industries in which a break in the flow of production would ruin the product. Petroleum and chemical plants are now completely automatic, from the basic raw materials to final packaging for shipment. A small group of engineers is still required to check the operation from a central control room.

How is automation used in industry?

The need for faster, cheaper production in modern mass industry has created the greatest demand for automation. Even the production of complicated high-precision items can be done by automated machines, in one smooth and continuous operation. Some industries, such as those using atomic energy,

43
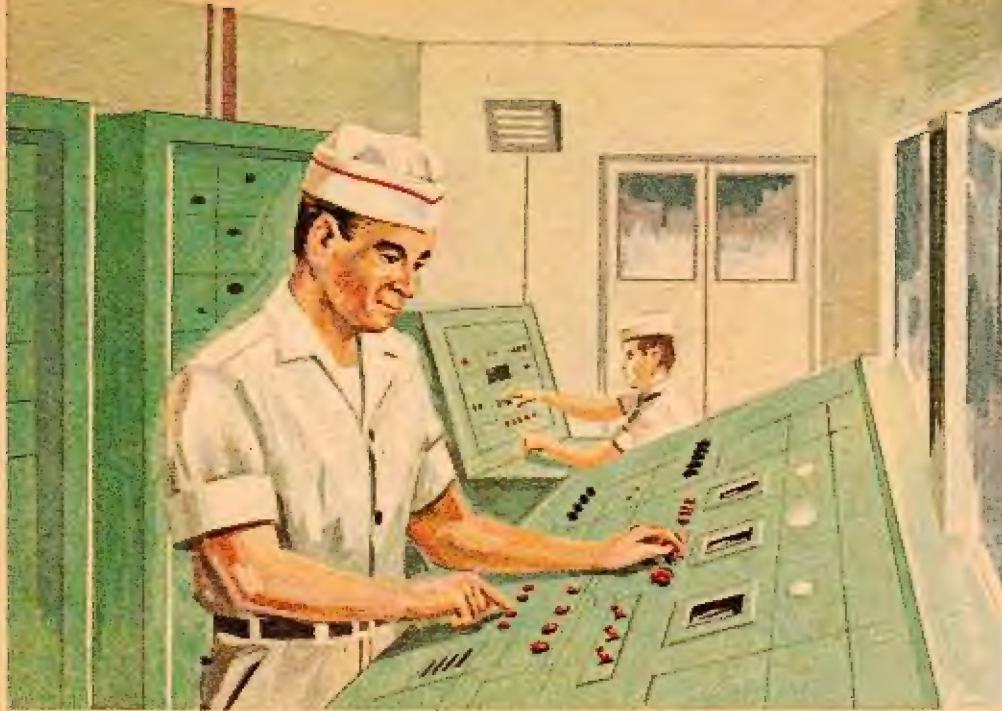
The automatic control equipment belongs to an analogue computer for the world's first fully automatic system for making ice cream mix. It calculates ice cream formulae and converts the information to coded punch cards. These in turn are translated through a batch-blending system to direct the flow of raw products from storage to blending tanks. Wouldn't it be a shame if the "robot" would develop a taste for ice cream and eat it up before it reaches you?

When people hear what the "Ice Cream Robot" can do, they may picture something like the illustration at the right. Actually, the robot is handling all of the operations, only it does not look like a tin man, but like a calculating machine.

must use automatic machinery because humans cannot work too near the nuclear reactors on account of the dangerous radiations that accompany the splitting of atoms.

Many automatic robot devices are now so common in our everyday lives that few people even take notice of them. Public buildings have self-service lifts; some of these even use tape-recorded messages to instruct passengers who hold up their progress. Central heating, automatically regulated by the thermostat, is another example.
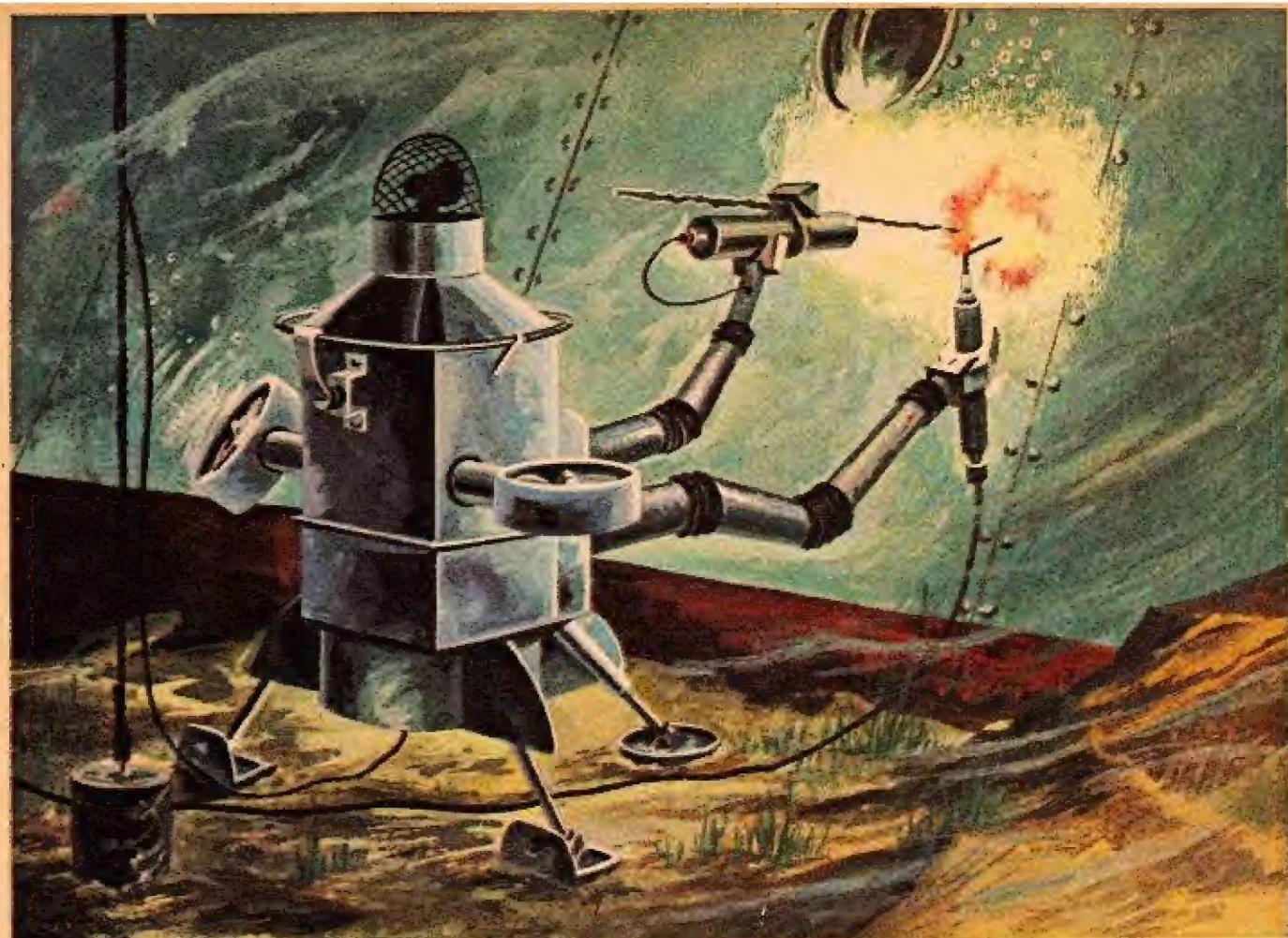
The underwater MOBOT can function much better than human beings at great undersea depth.

During the past decade there has been an increased interest in the sea as an important area for military expansion and as a source for food and raw materials. Thus, a growing need for performing complex underwater operations is being generated. Typical of the operations which can be performed by properly selected robot units are:

Can robots do tasks that man can not do?

Installation and adjustment of underwater detection devices.

Operation, inspection and maintenance of submerged equipment.

Exploration and sampling the ocean environment.

Location and recovery of objects lost in the oceans.

Underwater operations associated with oil well completion.

Underwater mining operations.

Underwater construction operations.

Attaching lines, clevises, slings, etc., to underwater objects.

Underwater geological and scientific explorations.

Underwater farming.

As shown in the illustrations here, Mobot can be adopted to many of these undersea jobs. This robot can see, it can hear, it can feel, it can operate drills, cutting torches, wrenches and other special tools; it will proceed to a specific destination, report to its operator, perform its functions, deal with emergencies, carry out alternate decisions — all

45
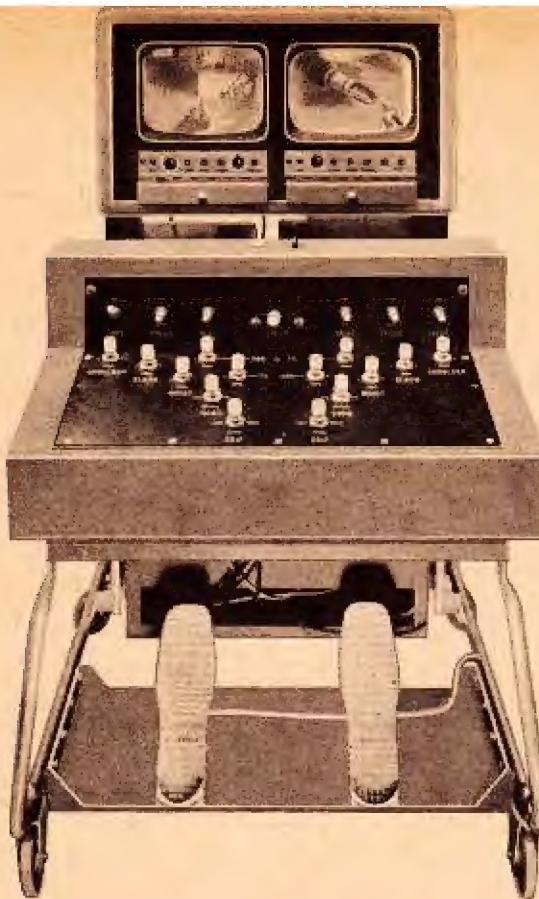
Telemetry control panel is used to control the underwater Mobot on page 45.

at the command of the operator on board a surface vessel.

Telemetry is the term given to the

What is telemetry?

process of detecting and gathering information at one location and relaying it to another spot automatically. Many common devices that we see everyday employ telemetry. For example, the temperature gauge on the dashboard of an automobile tells the driver, sitting in the car's front seat, about the temperature in a different location — inside the car's engine. When mechanical robots are used for telemeter purposes, in addition to gathering data, they can also do actual work. We are now employing them for both undersea and outer space tasks.

Any man would be bold indeed to attempt to spell out today

How far can we go?

what robots and electronic brains may some day accomplish. There can scarcely be any doubt, however, that machines are doing more and more things better than people. We have long since become used to that fact, especially when it comes to machines that supply physical muscle; a man with a shovel is no match for a bulldozer in an earth-moving contest. We are beginning, too, to realize that man can be equally outclassed by machines that supply power ordinarily considered unique to the human brain; an electronic computer may complete a problem in an hour or two that it would take a mathematician years to solve with paper and pencil.

But we must remember that a machine can only do what it is specifically programmed to do. At best, it can never do more than that; it may do less, if it blows a fuse or runs out of petrol. When it comes to judgment, common sense, or whatever you want to call it, the machine is out of the running.

It is not by some coincidence that people can do things that machines cannot do, and vice versa. It is, of course, the reason that man made the machines in the first place. He harnessed power to extend his strength and devised automatic controls to rid himself of undesirable, repetitive tasks.

As technological progress continues in the future, presumably machines will continue to do more and more of our chores, but only as the tools of the human beings that use them. The ma-

chines will supply brawn and brain muscle; people will supply the intelligence, foresight, tact, drive, and other human qualities needed to run a business.

Science fiction stories and horror comics notwithstanding, machines are not going to take over the world. In the business world, machines without people are as worthless and helpless as a hammer or screwdriver is when there is no hand to guide it.

Computer Talk

ACCESS TIME. The time it takes your computer to find a fact in its memory storage . . . also the time to find the spot to store it in the first place.

ADDRESS (noun). A designation – numbers, letters, or both – that indicates where a specific piece of information can be found in the memory storage.

ADDRESS (verb). To call a specific piece of information from the memory, or to put it in.

ANALOG COMPUTER. A computer (or calculating device) that operates by translating numbers into measurable quantities such as voltages, resistances, rotations, or vice versa.

ARITHMETIC SECTION. This is the part of the processing unit that does the adding, subtracting, multiplying, dividing, and makes the logical decisions.

BINARY DIGITS. The kind of numbers that computers use internally. There are only two binary digits, 1 and 0, otherwise known as "on" and "off." They are known as bits.

BYTE. A special size of computer word containing 8 'bits' or series of 1's and 0's. Most computers now made use this number of bits as a unit.

CHANNEL. One-way traffic roads for the flow of information bit-by-bit, or word-by-word, either into the computer or to and from the storage.

COBOL. A common computer language used by men in business. The initials stand for Common Business Oriented Language and the language used is similar to English.

CODING (noun). A system of symbols and rules that tell the computer how to handle information . . . where to get it, what to do with it, where to put it, where to go for the next step, etc. (See *Programme*.)

COMMON LANGUAGE. A technique that reduces all information to a form that is intelligible to the units in a data-processing system. This enables the units of the computer to "talk" to one another.

COMPARE. To check information – alphabetical, numerical or symbolic – against ostensibly related information in order to determine whether it is identical, larger or smaller, or in sequence.

COMPUTER WORD. A series of 1's and 0's that are grouped into units. These words are intelligible to the computer and represent alphabetic, numeric and special characters.

CONTROL SECTION. Nerve centre of the electronic brain. It prescribes a chain of instructions (a programme) for every bundle of facts that enters the system. It can send for stored data when it is needed during the programme. It can examine the results of any step to select the following step or steps. When one bundle of facts has been processed, the control section usually issues orders to start all over again with the next one.

DATA REDUCTION. The computer job of bringing large masses of raw data down to its simplest form, and organizing it in an ordered and useful manner.

DIGITAL COMPUTER. A computer (or calculating device) that operates by using numbers to express all the quantities and variables of a problem. In most digital computers, the numbers, in turn, are expressed by electrical or electronic impulses.

FORTRAN. A common computer language used by mathematicians, engineers and scientists. The initials stand for Formula Translation Language. It allows the writing of programmes in a mathematical equation form.

INPUT. Computer fodder in the form of bundles of new facts.

INPUT-OUTPUT DEVICE. A unit that accepts new data, sends it into the computer for processing, receives the results and converts them into a usable form, like payroll cheques, or bills.

INPUT STORAGE. First stop for incoming information. Picks it up so that bundles of information can get into the system without waiting for the previous ones to come out the

other end. Enables consecutive bundles to be compared with each other.

INTERMEDIATE STORAGE. A sort of electronic scratch pad. As input is turned into output, it usually goes through a series of changes. The intermediate memory storage holds each of the successive changes just as long as it is needed.

INQUIRY UNIT. A device used to "talk" to the computer, usually to get quick answers to random questions like, "How many hammers do we have in stock?" or "When did we last order soap powder and in what quantity?"

INSTRUCTION. A coded programme step that tells the computer what to do for a single operation in a programme.

LOGICAL CHOICE. Making the correct decisions where alternatives or even a variety of possibilities are open . . . whether to debit or credit . . . whether or not to issue a replacement order.

MEMORY STORAGE. The computer's filing system. It holds standard or current facts such as rate tables, current inventories, balances, etc., and sometimes programming instructions. The memory storage can be internal, that is, a part of the computer itself, such as drums, cores or thin-film. It can also be external such as paper tape, magnetic tape or punched cards.

MAGNETIC CORE STORAGE. A type of computer storage that employs a core of magnetic material, wound around with wire. The core can be charged to represent a binary 1 or 0. It provides for very fast access to and from system storage.

MAGNETIC DRUM STORAGE. A metal cylinder, with a sensitized surface, which spins inside a jacket with reading-writing heads. The address of every bit of data on the drum is known, so it is merely a matter of dropping it into its "cubbyhole" or fishing it out as it passes under the right head.

MAGNETIC TAPE STORAGE. Reels of metallic or plastic tape with sensitized surface. Much like paper tape, except, that instead of punching a hole, you charge up a spot. Data can be read, erased, entered or replaced by recording heads. Data is usually entered in sequence so that your computer handles the facts in logical order at breakneck speed.

OUTPUT. Computer results such as answers to mathematical problems, statistical, analytical or accounting figures, production schedules . . . whatever you may desire.

OUTPUT DEVICE. The unit that translates computer results into usable or final form. (See *Input-Output Device*)

PRINTER. An output device for spelling out computer results as numbers, words or symbols.

PROCESSING SECTION. The unit that does the actual changing of input into output . . . includes arithmetic section and intermediate storage.

PROGRAMME (noun). A set of instructions or steps that tells the computer exactly how to handle a complete problem — whatever it is. Most programmes include alternate steps or routines to take care of variations. Generally, programme steps form a complete cycle. Each incoming bundle of facts (unit of information) sets off the whole cycle from start to finish; the succeeding unit sets it off again and so forth.

PROGRAMME (verb). To plan the whole operation from input to output and set the control section to handle it.

PROGRAMMER. Person who arranges the program.

REAL-TIME. A method of processing data so fast that there is virtually no passage of time between inquiry and result.

REGISTER. A device in which information is placed for storage or other purposes.

STORED PROGRAMME. A set of instructions in the memory section that can run the computer or cut in to take over from the regular programme when the occasion arises. Often used for alternate routines.

The robots on the title page are automatons built by General Electric for the World's Fair in New York in 1939. Operated by electronics, Electro could say 77 words and Sparko could bark.
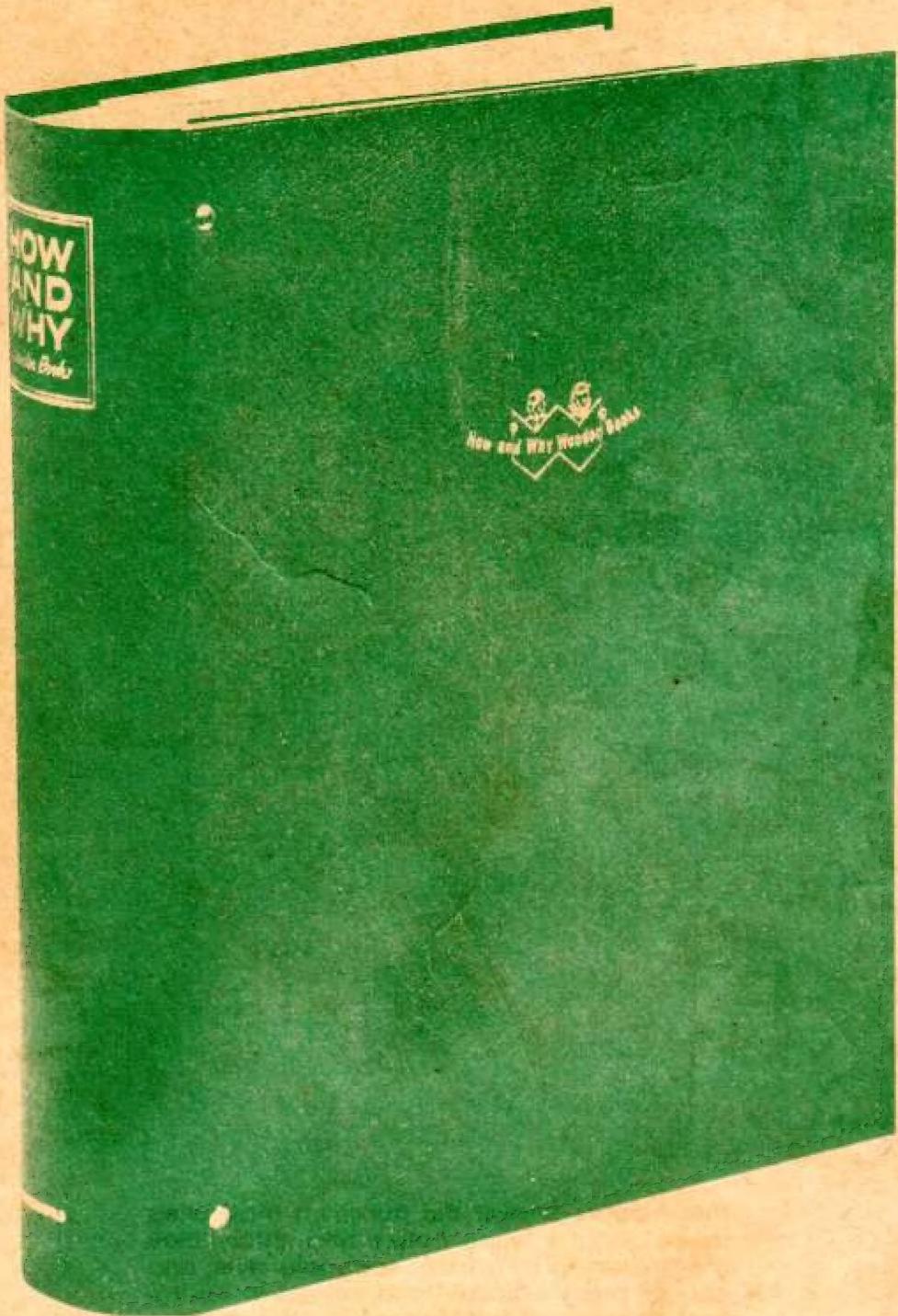
HOW AND WHY

These books answer the questions most often asked about science, nature and history. They are presented in a clear, readable style, and contain many colourful and instructive illustrations. Readers will want to explore each of these fascinating subjects and collect these volumes as an authentic, ready-reference, basic library.